LECTURES ON GOLD.

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LECTURES ON GOLD

FOR THE INSTRUCTION OF EMIGRANTS ABOUT TO PROCEED TO AUSTRALIA.

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BY

Joseph

J. BEETE JUKES, M.A. F.G.S.

EDWARD FORBES, F.R.S.

LYON PLAYFAIR, C.B. F.R.S.

...gton Wilkinson W. W. SMYTH, M.A. F.G.S.

JOHN PERCY, M.D. F.R.S.

ROBERT HUNT, KEEPER OF MINING RECORDS.

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The following Lectures were delivered in the Museum of Practical Geology, in consequence of a request from the Council of the Society of Arts. A deputation from that Society, appointed to confer with the Director and Professors of the Government School of Mines and of Science applied to the Arts, stating that the necessity of a course of Lectures on Gold had been urged upon them by intending Emigrants, it was thought that the resources of the Museum of Practical Geology and of the Government School of Mines would afford great facilities for such a course of Lectures as would prove instructive to Emigrants about to proceed to Australia; upon which suggestion the course now printed was immediately arranged.

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ON THE GEOLOGY OF AUSTRALIA, WITH ESPECIAL REFERENCE TO THE GOLD REGIONS.

BY

J. BEETE JUKES, M.A. F.G.S.,

LOCAL DIRECTOR OF THE GEOLOGICAL SURVEY OF IRELAND ; AUTHOR OF "THE VOYAGE OF THE FLY," "SKETCH OF THE PHYSICAL STRUCTURE OF AUSTRALIA," &c. &c.

J. BEETE JUKES, M.A.

ON

THE GEOLOGY OF AUSTRALIA.

I APPEAR before you to-night, ladies and gentlemen, as the representative of Professor Ramsay, who is absent from London on the duties of the geological survey. In his absence Sir H. De la Beche has requested me to give the following Lecture, because, having some years ago visited Australia, and seen something of all its colonies, and parts of the coast not yet settled, I could speak with a little more confidence than one who was an entire stranger to it.

As I must necessarily suppose that the majority of those I am now addressing are unacquainted with the science of geology, you must allow me to commence with such a rapid sketch of some of the outlines of the science as will enable you to understand certain terms that I must use when speaking of the geology of Australia. All large accumulations of earthy matters, whether hard

or soft, are, for convenience sake, termed by geologists "rocks." These are of two kinds, stratified and unstratified. The stratified have all been deposited in water, and are, therefore, also called aqueous rocks, and consist principally of sand, clay, and lime. The sandy rocks are sand, sandstone, gritstone, gravel, pudding-stone, or conglomerate; the clayey rocks are clay, clunch, marl, shale, and slate; and the lime rocks, chalk, limestone, marble, &c. These rocks having been gradually and successively deposited in water through an immense series of ages, have necessarily a certain order or sequence. One set of rocks was deposited in the earliest ages; these, as being the first formed, are called "Primary" rocks. In succeeding ages another set was formed, which are called "Secondary;" and after those another, which are called "Tertiary:" and it is clear, from the very nature of their formation, that the order of their relative ages must be the order of their superposition, or the way in which they repose one upon the other. The "Secondary" rocks can never be found under the "Primary," nor the "Tertiary" under the "Secondary." As, however, no one rock or set of rocks is continuous over the whole globe, it is clear that there might be many places where, for instance, no Secondary rocks had ever been formed, and in those cases there might be Tertiary rocks resting directly on the Primary ones. The geological sequence, or regular series of rocks, therefore, might be broken, but could never be inverted. There may be no place in the world where the whole series of aqueous or stratified rocks repose one upon the other in one complete unbroken series; but there is

no place where one rock or set of rocks, after being once found above another set, will ever be found below it.*

Nearly all stratified or aqueous rocks are what is termed fossiliferous, that is to say, they contain the remains of animals and plants: the leaves and the stems of trees, shells, fish, and other marine and freshwater animals, and sometimes the bones and harder parts of animals that lived upon the land.

This part of geology will form the subject of the next lecture. I mention it now, in order to explain the meaning of one term especially. The Primary, Secondary, and Tertiary sets of rock, as also the several parts into which those great classes of rock can be subdivided, are each characterised by containing peculiar sets of fossils. Geologists, therefore, adopt terms having reference to these fossils by which to designate the series of rocks. One of these terms is "Palæozoic," which means "characterised by ancient animals." The Palæozoic rocks may be said to include the Primary rocks as far down as fossils have been found in the latter.

The unstratified rocks have all been molten or fluid by the action of heat, and are, therefore, called igneous rocks. They are almost all very hard, and their internal structure is usually crystalline; the small particles of which they are made up, instead of being rounded grains, like those of sandstone, are, more or less perfectly formed crystals,

* In very highly disturbed and contorted districts, such as the Alps for instance, a set of rocks may be tilted over and placed bottom upwards, but that has evidently nothing to do with the original order of their formation.

interlaced and entangled one with the other. Igneous rocks are of various kinds, such as "lava," the produce of volcanoes; "basalt," a heavy black rock, the crystals of which are scarcely discernible, even with a microscope, and which often forms columns more or less perfect, like those of the Giant's Causeway; "greenstone," which differs from basalt chiefly on account of a slight difference in its mineral constituents; and various kinds of trap rocks up to porphyry, syenite, and granite. Granite is a confusedly crystalline mass of three minerals, called quartz, felspar, and mica. These unstratified, or igneous rocks, observe no order of position either in time or space. They were all formed below the others originally, in the bowels of the earth, whence they have been thrust and protruded upwards by those great disturbing agencies of which the earthquake and the volcano are superficial symptoms.

You will easily understand that when great masses of igneous or molten rock were thrust in among, and protruded through, the aqueous rocks, these latter must have been greatly affected by the intense heat of the former, and sometimes so much so as to lose, more or less entirely, their original characters of aqueous rocks and assume many of those of igneous origin. We have, therefore, from this source a third class of rocks intermediate between the other two, a class which from their altered condition are termed Metamorphic, or transformed, rocks. The principal varieties of these are gneiss, which is like laminated granite, mica slate, chlorite slate, &c., and clay slate. Any of the aqueous rocks, whether Primary, Secondary, or Tertiary, may become altered or Metamorphic rocks;

but as the Primary rocks are the lowest, and therefore nearest to the source of heat, and, moreover, are the oldest, and have therefore had more chances of being affected by it than the others, so the Metamorphic rocks are usually Primary rocks, and most commonly lie at the bottom of those Primary rocks. The most general characteristic of the Metamorphic rocks is to split not along the grain of their bedding, but in some given general direction across the bedding. This superinduced fissile structure is called the "cleavage."

When the igneous rocks were intruded by main force among the aqueous ones, lifting them up and pushing through them, they naturally caused cracks and fissures to run in various directions. To many of these cracks and fissures the molten rock gained access and filled them up, forming what are called "dykes" and "veins;" others, however, were not so immediately filled up, but remained more or less open until subsequently filled with mineral matters accumulated by a more slow and gradual process. As the igneous rocks cooled, moreover, they themselves cracked, or were acted on, by subsequent disturbing forces which caused fissures to run through them as well as the surrounding aqueous rocks. All these fissures or veins have since been filled (we have no time to attempt to explain how) by minerals in a more or less pure or unmixed state, and frequently in a crystalline form. Of these minerals quartz is probably the most abundant. Quartz is usually a white compact opaque stone, but sometimes forms long finger-like transparent crystals, and is then called "rock crystal." It may be called "pure flint."

Besides quartz, however, many other minerals accumulated in these veins, and among them many metals, such as lead, tin, copper, silver, and gold. The other metals are rarely found pure, but occur as ores combined with other substances in such a manner that they often lose all their metallic appearance, and can only be recognised by the practised or scientific eye. Gold, however, most frequently occurs pure, or, at all events, so nearly so that its metallic nature can be at once recognised. It occurs in these quartz veins either in crystals or in rudely shaped lumps and masses, or in small flakes and grains, and sometimes is diffused through the mass of the quartz in such a minute state of subdivision as to be quite imperceptible to the eye, although in such quantity as to be very profitable to the miner.

The metals mentioned above, then, usually occur in narrow, more or less upright veins, which are nothing more than comparatively small cracks or fissures traversing the whole mass of rock in which they are found. These veins are rarely more than a few feet, sometimes only a few inches wide.

The metals are not entirely confined to such veins, as sometimes they are found in strings, or nests, or irregular masses, in the body of the rock, or disseminated through it in a state of fine subdivision. It is very rarely, however, that any considerable quantity of gold or other metal is thus found dispersed in the body of a rock.

There is one other general geological subject I must briefly lay before you, and that is the formation of drift gravel, sand, or clay,—those loose, unconsolidated mate-

rials which are so commonly found lying between the vegetable mould and the main body of the solid rock.*

It is well known that not only have all the stratified rocks, comprising the far greater portion of the globe, been formed under water, principally under the sea; but also that, since their formation, they have been raised into dry land, again depressed beneath the sea, and again re-elevated, and this process repeated, perhaps, many times. This alternate elevation and depression of the land has, moreover, taken place more or less quietly and gradually, the result of which is, that every portion, nay, every square inch of dry land, has passed through the influence of tides, and currents, and breakers, and all that destructive action which we now see taking place along our own coasts daily. The result of this is, that the last time the land slowly emerged from the sea, the breakers, the waves, and the currents, knocked off fragments of rock, washed and rolled them, and swept them about until they had rounded them into boulders or pebbles, pounded them into sand, or ground them down into mud or clay. These clays, sands, and gravels, the washings of the rocks, have finally been left lying about in patches here or there, or spreading over more or less of the surface, sometimes covering large tracts, both high and low, sometimes accumulated only in hollows or pre-existing valleys and depressions. When the waters in which these superficial accumulations were deposited, acted on rocks containing gold, whether the

* It must be remembered that "*rock*" in the mouth of a geologist may mean soft sandstone or clay. It is his general term for all considerable masses of earthy matter.

gold were disseminated through the mass of the rock, or confined to the quartz veins traversing it, fragments of the auriferous rock would, of course, be detached equally with pieces of all other rocks. These fragments, either slightly water-worn, or altogether broken and ground down, would afterwards be found in the drift clays, sands, and gravels. But it is important to remark, that these drifted materials would, in all probability, be much richer in gold than the actual gold-bearing rocks themselves. This arises from the circumstance, that water moving with a given force or velocity, communicates motion to matters suspended in it, or lying on its bottom, according to their shape and specific gravity. Now the specific gravity of quartz and of most other heavy compact rocks is about $2\frac{1}{2}$, whilst the specific gravity of gold is 18 or 19. Gold, therefore, is somewhere about seven times as heavy as any rock or stone with which it is likely to be associated. A current of water accordingly having sufficient strength to bear along sand or pebbles of quartz or any other rock, might not be able to move the fragments of gold associated with them. Speaking roughly, it might be unable to move grains of gold the size of a pin's head, while it swept away fragments of rocks as big as peas. Moving water, therefore, has done for the auriferous rocks formerly, just what the miner would do now, break it, namely, up into fragments, sweep away the lighter particles, and leave the gold behind it.

No conceivable current of water would be able to carry very far large fragments of gold, or even large fragments of quartz, or other rock containing much gold.

Whenever, then, you find these large fragments, you may be sure you are not far from their parent site. Gold dust, on the contrary, especially if in the form of scales or spangles, may be carried over very considerable distances. In this way the actual total amount of gold may be pretty equally distributed over large spaces of auriferous drift, because the currents that had force enough to move the larger fragments a few hundred yards, would carry all the smaller ones miles away. In the one case, rich lumps would be dropped sparingly here and there; in the other, scales and dust would be sown broadcast, as it were, equably over the wide spaces where the currents began to lose their force and velocity. The same reasoning applies to the case of rivers. When we find gold in the sand of rivers, we must not, therefore, conclude that it was the actual water of the river that detached it from the parent rock. Doubtless it may do so sometimes, and to a small extent, but it is exceedingly unlikely that any river should have the chance of attacking many such auriferous spots in its bed. As the old drift would be naturally accumulated in the lowest hollows and depressions of the surface of the rocks, or in the old pre-existing valleys, and as the rivers of a country naturally follow the same course, it is from these loose and incoherent materials that a river derives its store of gold. A river traversing a country of auriferous drift is engaged in re-sifting and re-assorting the materials that have once been sifted by the waters in which the drift was formed, carrying all the matters that fall into it *forward,* but soon depositing the heavier among them and sweeping off all

the lighter particles into lower regions. As a river winds through its valley, it attacks first one bank and then another, eating into the base of a cliff where the full force of the current is shot against it, causing the perpetual falling of small portions of it into its waters, carrying those portions on, and then depositing them below in places where the force of the current is checked.

In examining a river for gold, therefore, it is the inside curve of its bends where sand-banks and spits are accumulating, or wherever the force of the current is slackened, and the materials carried by it are consequently dropped, that should be first searched. Similarly, where a river has cut down through the drift to the solid rock below, especially if hard jutting ribs of rock stretch across it, as is often the case, gold is most likely to be dropped on the upper side, and in the holes and crevices of these rocky bars, where they check the force of the stream, and catch any heavy matters that might be rolled along at its bottom.

Rivers are, indeed, *great natural cradles*, sweeping off all the lighter and finer particles at once, the heavier ones either sticking against natural impediments, or being left wherever the current slackens its force or velocity. A cradle is a wooden trough with several "cleets," or ribs fastened across its bottom. Into the head of it is placed a quantity of auriferous sand or gravel, water is poured over it, and motion communicated by rocking and tilting the cradle. The running water carries off all the lighter matters, and leaves the heavy stones and lumps of gold either in the head of the cradle, or accumulated at its

bottom against the "cleets," fastened across to arrest them. Turning the bed of a river, then, wherever such a manœuvre is practicable, is like a miner examining the bottom of his cradle; and if it happens to be done at the right spot, where there are several natural "cleets," or bars, or where there are holes in the rock for the gold to drop into, it is likely to be rewarded very richly by the accumulated result of centuries of natural gold washings.

We can now understand the difference between what are called "wet diggings" and "dry diggings;" the former are those carried on in the bed of a river, the latter in the general spread of drift lying over the country. We can now also understand why it is that gold washing, or the extraction of golden fragments from the drift of a country, is much more profitable than gold mining. In gold mining, vast quantities of hard rock have to be quarried and removed, to be crushed by powerful machinery, and to be washed over and over again, or to be treated by other expensive processes; while in gold washing, or separating gold from drift, all the mining and the crushing, and a good part of the washing and sorting, of materials have been already done for the miner by Nature.

There is one other possible reason why auriferous drift should not only be richer in gold than the mass of the rock from which it is derived, but also why the first deposited auriferous drift of a country, after the formation of the gold, should be richer than any subsequent one. Sir R. Murchison, in his account of the auriferous chain of the Ural, has remarked that the gold

there must be of comparatively recent geological origin,—that it is newer than any rock or earthy deposit in the country except the drift. The sands and gravels (now sandstones and conglomerates) of the old Palæozoic, Secondary or Tertiary rocks, although made up of the detritus of the Ural chain, do not contain a grain of gold. It is most probable, therefore, that there was no gold in the Ural during the period of their deposition; and that the gold was only deposited in the veins of the Ural rocks just previously to the formation of the drift. Now it is believed, that auriferous veins (contrary to what is often the case with other metals, such as copper and lead) are richest near the surface, and get poorer the deeper they are followed. If that be the case, it follows that those portions of the auriferous quartz veins that were broken up during the period of the drift, being the most superficial portions, were comparatively richer in gold than equal portions of those now forming the superficial part of the rocks would be. Consequently, the auriferous drift derived from them would be proportionately richer than an equal quantity of similar drift would be if formed now. It may not be a quite sufficiently ascertained fact that gold veins are richest nearest the surface, but if they are the above reasoning holds good.

Having thus glanced at a few facts in general geology, I will now proceed to give an almost equally slight sketch of the geology of Australia.

You all know that Australia is one great compact land nearly as big as all Europe, with a large island, called Van

Dieman's Land, on the south-east of it. The straits between Van Dieman's Land, or Tasmania, and the continent of Australia, are called Bass's Straits. They are about 130 statute miles across. The straits that separate Australia from New Guinea are called Torres Straits; they are about 140 miles wide. Bass's Straits are about in the same south latitude as Spain in the northern hemisphere. Torres Straits are in a similar latitude to that of Sierra Leone. Sydney is in the corresponding latitude to that of Salee in Morocco.

"The great physical features of Australia, as far as they are at present known, may be very briefly described.

"1. A long but not lofty mountain-chain runs along the whole eastern coast, crossing Bass's Straits into Tasmania, and running under Torres Straits to the shores of New Guinea.

"2. On the landward, or western side of this chain, are great plains, declining gradually to the west, but at first often broken by detached ranges or groups of hills. These plains are, on the south, traversed by the Rivers Murray and Darling and their tributaries disemboguing into Lake Alexandrina; in the centre, by Victoria River (and perhaps some others), which drains into Sturt's central desert; and on the north by the small rivers which run into the southern portion of the Gulf of Carpentaria.

"3. West of the tracts thus described appear immense desert plains, spreading far and wide through the heart of the country, extending to the sea-coast round the Gulf of Carpentaria on the south, round the Great Australian

Bight on the north and all along the north-west coast from North-West Cape to Collier's Bay.

"As minor but sufficiently important features, may be mentioned,—

"4. The mountain-chain of South Australia, running north from Cape Jervis to the singular horseshoe-shaped depression of Lake Torrens.

"5. The high land of Western Australia, running north from Point D'Entrecasteaux and King George's Sound to the neighbourhood of Shark Bay.

"6. The high land which forms the coast from Collier's Bay to Wickham's Victoria River, and seems to stretch in an east and west direction across the interior of Arnhem Land, south of Port Essington, to the western shores of the Gulf of Carpentaria."*

The Great Eastern Chain.—This is in no case a single ridge of mountains. It is a broad tract of elevated ground, from which rise many mountain-ranges of very various size, character, and extent. These are sometimes steep and broken ridges; sometimes mere table lands. Great spurs frequently strike out on either hand, forming lofty and broken ranges of mountains, running to the sea-coast on one side, and striking into the interior on the other. On the west side of the chain there appear to be frequently small detached ranges, running north and south, or parallel to the main chain, occurring at intervals for two or three hundred miles from the water-shed. This

* Sketch of Physical Structure of Australia.

seems to be more especially the case in the province of Victoria.

Van Dieman's Land, or Tasmania, is a mountainous island, the highest points of which are 5000 feet above the level of the sea. From Count Strzelecki's description, granite shows itself in considerable force in several parts of the island; but the most conspicuous rock is a massive, largely crystalline greenstone, which forms great ridges called "tiers," running in various directions and enclosing small isolated valleys, usually called plains. These plains are commonly composed of sandstone, with subordinate beds of shale and limestone, and one or two beds of coal, belonging to a palæozoic formation, probably not greatly differing in age from the Devonian rocks of Europe. From the north-eastern point of Van Dieman's Land a chain of high rocky islets, consisting chiefly of granite, leads across Bass's Straits to the granite ridge of Wilson's Promontory. From this point the water-shed of the Great Eastern Chain runs north and north-east to the Australian Alps, gradually rising in elevation till it attains in Mount Kosciusko the altitude of 6500 feet. These mountains are usually called in Australia the Snowy Mountains, and if not covered by perpetual snow, are covered by it for a sufficiently great portion of the year to give rise to the perpetually flowing stream of the Murray River from their western flank. Granite, and other similar rocks, together with mica slate, and other metamorphic rocks, compose these mountains. Palæozoic sandstones, however, occur on their flanks, and are seen near Melbourne, and coal has been found at Western Port. From the Australian

Alps to the Moreton Bay district the chain continues with its water-shed at a distance of from 70 to 100 miles from the coast, none of its peaks apparently rising higher than about 4000 feet above the sea. Granite frequently shows itself in great force, covered by metamorphic rocks; and these again covered by palæozoic rocks, of which hard thick sandstones are the most conspicuous feature. One great palæozoic tract occupies the country around Sydney for many miles, spreading also over all the Hunter River district. North of Moreton Bay the constitution of the chain is only known from observations made upon the coast, and those made by Dr. Leichardt in his overland journey to Port Essington. He describes many fossilliferous sandstones and limestones probably palæozoic, and mentions the occurrence of coal; he also describes large granite tracts with metamorphic rocks, and great masses of basalt and greenstone, and other igneous rocks. Similar rocks form the many mountain-ranges that strike out upon the coast, as observed by myself when Naturalist to H.M.S. Fly. From Cape Upstart to Cape Melville especially, many great granite ranges, the summits of which were in several instances 4000 feet high, were observed. North of Cape Melville the hills gradually decline in height, rarely equalling 1000 feet, but being still often composed of granite, till about Cape York they are not more than 400 feet, composed chiefly of porphyry. The submarine continuation of the chain, however, may still be traced across Torres Straits by a line of steep rocky islands, 700 or 800 feet high, composed of granite or similar rocks up nearly to the shores of New Guinea.

The length of the chain, measured from the South Cape of Tasmania to the northern part of Torres Straits, is 2300 statute miles in a direct line.

In sailing along the coast one is frequently struck with the strange outline of the hills. The Pigeon House, Hat Hill, Mount Camel, Mount Dromedary, Cape Upstart, Mount Funnel, are names that were suggested to Cook by these strange forms. In attempting to traverse them, the deep narrow gorges and ravines, the frequent and lofty perpendicular precipices, are found to be their most prevailing characteristics.

Three miles at the back of Hobarton rises Mount Wellington, 4200 feet above the sea, ending in grand precipices of huge columnar greenstone. So numerous are the dark gullies and ravines that indent its flanks, that people have been lost in endeavouring to ascend it, and in some instances no trace of them has ever since been discovered, notwithstanding the most diligent search. An immense unbroken forest of gum-trees (the bush) increases the intricate and impenetrable character of the country, while dense scrubs or thick impervious belts of bushes and shrubs occur in the lower and moister grounds.

The late Captain Booth, when Commandant of Port Arthur, in Van Dieman's Land, lost his way in a scrub within three or four miles of his own house, and was only discovered at the end of five days' search by the united efforts of the troops under his command. Count Strzelecki had to abandon all his horses and baggage, when exploring Gipps' Land, and only extricated himself and his com-

panions by many days' cutting through the scrub, sometimes only advancing two or three miles a-day.

The "bush," or the comparatively open forest of gum-trees, is like a great untidy expanse of gravel walk, covered with small ironstone nodules, with here and there a little brown straggling grass, like living hay. The trees stand pretty widely apart, with little or no underwood, their bare lofty stems not branching for a considerable height, and having loose strips of ragged bark, like worn-out matting, hanging from them. The leaves are few, small, and scattered, giving but little shade, so that it is often hotter in the bush than in the open country, as the trees impede the free current of the air. Old prostrate rotten trunks and dry broken branches lie here and there on the bare brown ground, often blackened from fire, the living upright trees frequently exhibiting a scorched and blackened surface from the same cause. The gum-trees spread over the rockiest and barest ground, where scarcely a particle of what we should call soil is to be seen. Sometimes, especially on the seaward slope of the hills at the foot of the precipices, where some moisture falls and soïl accumulates, a different description of forest is found, called "brushes." These, especially as we go north towards the tropics, consist of lofty and umbrageous trees, with great cable-like creepers or lianas climbing from tree to tree, while groups of elegant palms rise here and there, or clusters of tree-ferns, with their tentlike canopies. "Plains" in Australia are open, park-like districts, with merely clumps of trees standing at intervals, the undulating ground being covered

with fine grass, that after rains is rich and luxuriant, rising to the horse's belly as one rides through it. This, however, in long droughts, dies and withers away, and the "plains" are then mere undulating expanses of sand and dust.

A stranger, at first landing in the country, is always struck and unfavourably impressed with the sombre and monotonous tint and aspect of the evergreen vegetation. When the eye, however, is a little accustomed to this, it soon begins to detect shades and variety of beauty; and in the spring month of September, when refreshed by the winter's rain, the vegetation assumes somewhat of the greenness and freshness of our own insular climate.

In order to give a little more definite notion of the country, I will rapidly describe the neighbourhood of Sydney and that of Port Phillip.

On approaching Port Jackson, the coast is found to consist of perpendicular cliffs of white sandstone, varying from one to three hundred feet in height. They are broken through at one part by the opening that leads into the sandy and desolate harbour of Botany Bay; and a few miles north of that is a small indentation that Cook considered to be merely a boat harbour and called Port Jackson from the name of the look-out man at the mast-head. On sailing at this indentation, however, it is found that, like scenes at a theatre, one portion of cliff here stands back from the others, and admits of an entrance on either side of it. The entrance on the right leads into the North and Middle Harbours, which are still pretty nearly as lonely and deserted as when Cook first sailed along the coast.

The entrance on the left leads into Sydney Harbour, a long lake-like expanse of blue water branching into a multitude of coves, and bays, and winding arms, bordered for the most part by perpendicular cliffs of white sandstone, but with sandy beaches here and there. Four or five miles from the entrance stands the city of Sydney, surrounded by coves and bays, stretching its now handsome lines of houses and well-built suburbs over a great extent of ground, and assuming somewhat of a metropolitan character worthy of its extent of country. A long winding arm of the harbour runs seventeen miles farther up to Paramatta. Beyond this we find a wide, gently undulating plain, but little raised above the sea, for the next thirty or forty miles. This low land is composed for the most part of dark shale, which rests upon the sandstone that surrounds Sydney. On approaching the hills the sandstone comes up again to the surface from beneath these dark shales, and rises very gradually on to the flanks of the Great Chain, which here goes by the name of the Blue Mountains. The distant aspect of the Blue Mountains is that of a moderate level-topped ridge with a few eminent peaks and bosses rising from it here and there. It formed, however, for many years an impassable barrier to the colonists, the reason of which we shall easily understand if we come to examine it more closely.

I once had a good view of the Blue Mountains from the top of a lofty rock on the east side of the Hawkesbury River not far from Mulgoa. The river here flows north and south, parallel to the course of the mountains, running in a small ravine, of some 200 feet depth, along the

foot of their eastern slope and receiving the drainage of that portion. From this ravine the ground sloped gently upwards to the west for many miles, till it attained a height of upwards of 2000 feet. It had a uniform general surface, so that its horizon formed a straight line, over which a few peaks appeared rising to about 3000 feet. This gently sloping inclined plane, if it can be so called, was worn and furrowed by an infinite number of winding and branching gullies and ravines, so that its whole area seemed about equally divided between these furrows and their separating walls of rock. Each gully had perfectly precipitous sides, with overhanging ledges of rock jutting out at intervals, and the deep bottom of each was occupied by the bed of a dark torrent, that then was for the most part dry, or had only a little trickling stream from one deep pool to another, but after long-continued rain would be filled by a furious rush of water foaming along the whole bottom of the ravine. Far as the eye could reach, one great inextricable maze or net-work of these deep, impassable glens branched in every direction, with sometimes but a few yards of ground between them. Still the whole country was covered by the everlasting "bush," or forest of gum-trees, so that it was only from some higher cliff than usual, like that I was upon, that anything like a general view of it could be gained. The higher we go on to the flanks of these hills, the deeper and grander do these ravines become, so that, as described by Mr. Darwin and Mrs. C. Meredith, they at length assume the character of great gulfs or bays, 1000 or 1500 feet deep, with grand vertical precipices of this

height winding round them in headland after headland, like the cliffs of some great sea-shore. At the one near the Weather-boarded Hut, on the Bathurst road, Mr. Darwin says one could drop a stone from the summit of the cliff and see it strike the trees below, while it would be necessary to make a circuit of sixteen miles before a place could be found allowing of a descent into the valley. These ravines are characteristic of the sandstone formation mentioned before, and are shown on a smaller scale in the many winding arms and bays of Port Jackson and Broken Bay, and other harbours on the coast. We learn, from the sections of Count Strzelecki, that underneath the sandstone, on the flanks of the Blue Mountains, are certain shales containing beds of coal. These coal-beds rise also from under the sandstone at Bulli, and appear in the cliffs of the Wollongong and Illawarra district, fifty miles south of Sydney. They also appear from under the same sandstone at the Hunter River, one hundred miles north of Sydney, where they are worked at Newcastle. We see, then, that the country between Sydney and the Blue Mountains is slightly basin-shaped, the Sydney sandstone rising up from under the central shaly district in every direction, and the coal appearing wherever its lower beds come to the surface. I estimated the thickness of this Sydney sandstone at 800 feet; Mr. Dana assigns it a thickness of 1200.

If we cross the Blue Mountains towards Bathurst, we find metamorphic and granitic rocks rising from under this palæozoic formation, and forming all the country for some distance to the west. Bathurst Plains are them-

selves 2300 feet above the sea, almost surrounded by mountains, among which spring the upper branches of the Macquarrie River. About thirty miles west of Bathurst is a group of hills called the Conobalas, 2300 feet higher than Bathurst, or 4600 feet above the sea. These hills are said to be formed chiefly of mica slate; and on their flanks, in the bed of the Summer Hill Creek and the Lewis Ponds River, the first gold was found.

On approaching Port Phillip we sail up an open bay with comparatively low wooded land all round it. At its north-western corner is a narrow opening, scarcely perceptible till we enter it; passing through which we find ourselves in a large expanse of salt water that looks at first like another sea. It is, in fact, thirty or forty miles across, but on reaching its centre, the low shores, with just the tops of the trees, are visible on the horizon all round. On our left is Geelong, and before us is the Yarra-Yarra creek, with Melbourne on its banks. Far in the distance, on our right, can be seen some of the ridges of the Great Eastern Chain, stretching from Wilson's Promontory towards the Australian Alps; while, more to the left, groups of conical hills rise at intervals from the plain twenty or thirty miles distant, and 2000 or 3000 feet in height. In the neighbourhood both of Geelong and Melbourne are found beds of hard sandstone, their strata contorted and tilted at various angles with the horizon; these are most probably palæozoic sandstones; upon them rest horizontal tertiary rocks. At New Brighton, south of Melbourne, these tertiaries are dark brown ferruginous sandstones with casts of sea-urchins and sea-shells, and the leaves

of dicotolydenous trees. Near Geelong they are soft yellowish limestones, with the same marine fossils. Dark streams of black cindery lava may be traced here and there in both localities, sometimes decomposed on the surface and covered with vegetation; but in many places still as bare as if recently ejected from a volcano. I am not aware, however, of any actual crater being known in this immediate neighbourhood.

From Port Phillip to the Glenelg River the tertiary limestones probably stretch almost continuously, broken towards the north by many hills, some of which are extinct volcanoes with their craters still perfect. North of these are several north and south ranges of considerable altitude, of which the Mount Alexander range and the Pyrenees appear to be granitic and metamorphic, the Grampians, composed principally of thick sandstones, probably palæozoic, resting upon igneous rocks. Granite shows itself in the upper part of the Glenelg, its lower portion flowing through picturesque cliffs of the tertiary limestone.

From the Glenelg to Lake Alexandrina, and the Murray, are plains of tertiary limestone, part of which is called the "Biscuit Plains," from some curious flat circular concretions like biscuits in shape and appearance, lying on the surface of the ground. All the lower part of the Murray River is surrounded by the tertiary rocks, which in South Australia are called the "fossil formation."

The mountain-chain of South Australia, celebrated for its copper and lead veins, is composed principally of gneiss, mica slate, chlorite slate, and clay slate. The rocks are frequently traversed by great quartz veins, but there is

said to be no granite anywhere in the chain. It is possible that to this circumstance may be due the absence of gold, but too little is as yet known of the cause of the occurrence of gold in any place to warrant us in directly asserting this. The plain around Adelaide between the hills and the sea is again composed of the tertiary limestones.

In the interior of South Australia, Captain Sturt describes, east of Lake Torrens, Stanley Range as exhibiting granite, and Grey Range as composed principally of quartz rock. He penetrated N.N.W. from the latter nearly into the heart of the Australian continent, finding everywhere a vast, almost impenetrable desert, except in the oasis of Cooper's Creek. He describes large tracts as covered by ridges of loose sand, 100 or 150 feet high, the base of one touching the base of the other, and running in parallel lines in each direction to the horizon. He likewise traversed a great flat, depressed tract, which he describes as an ironstone plain on which his horse's hoofs rang, but left no track. Beyond that was still a sandy, uninhabitable desert, the only living things being a few blades of dry grass here and there, and a few small jerboas.

This great desert plain is in just the corresponding latitude to that of the desert of Sahara in the northern hemisphere, and seems to have much of its character. Three years ago Dr. Leichardt set off from Moreton Bay to endeavour to cross it to Swan River, and it is feared that he and his companions have perished in the attempt.

Between South Australia and Western Australia, the shores of the country only are known; they were surveyed by Captain Flinders by sea at the beginning of this

century, and were traversed on land by Mr. Eyre about fifteen years ago. Along the great Australian Bight, from Anxious Bay to Cape Arid, a distance of more than 700 miles, there is for the most part one unbroken cliff from 400 to 600 feet in height, composed of the horizontal beds of the tertiary limestone, with granite appearing from beneath it, both on the eastern and western extremity. The interior of the country appeared to be an arid level plain, stretching unbroken into the boundless interior. Not a water-course of any kind was met with, and Mr. Eyre made three successive journeys of seven or eight days a-piece, with only so much water as he could carry with him on horseback on each occasion. The water was only procured from places where it trickled out at the base of the cliffs.

The mountain-chain of Western Australia is rather an elevated district than a mountain-chain, with groups of hills rising from it here and there. It is composed of granite and metamorphic rocks, exactly such as those in which gold is usually found, but we have as yet heard no accounts of its discovery. Neither does it at all follow from the nature of the rock that gold necessarily exists. Gold is never found *in situ* except in such rocks, but hundreds of square miles of those rocks may anywhere occur without the presence of gold. In penetrating from the settled parts of Western Australia, towards the interior of the country, they have hitherto always come on large desert tracts of sand, covered with shrubs and bushes that love an arid soil. These are called the "sand plains," and look as if they were the edge of the great desert

interior. On the western coast there is a tertiary plain, some twenty miles wide, about Swan River, between the hills and the sea, composed either of a soft red sandstone, or a fine white, slightly calcareous sand, sometimes compacted together into an imperfectly consolidated limestone.

About lat. 29°, palæozoic rocks and coal were found, some years ago, by Messrs. Gregory, completing the analogy between the eastern and western coasts; the palæozoic rocks having in each case the same fossils.

Along the north-west coast, from Shark's Bay to the Buccaneer Archipelago, another low and desert tract occurs—all the voyagers describing it as a great illimitable plain covered by salsolaceous plants, fronted by low sandhills running along the back of the beach. This is probably another extension of the great central desert.

From Collier's Bay to Wickham's Victoria River, however, the country is again described as lofty and broken, the rock being principally a very thick-bedded sandstone worn into precipitous gullies and ravines like the Sydney sandstone.

Dr. Leichardt described a similar sandstone country rising into a high table-land in the country west of the Gulf of Carpentaria, forming bold and lofty cliffs, from which he had great difficulty to descend, about 150 miles south of Port Essington. At the foot of these cliffs he found granite and similar rocks.

The northern part of Arnhem Lend, between Anson Bay and the Gulf of Carpentaria, is low and flat, composed of soft red and white sandstones, highly ferruginous,

which are supposed to be tertiary, but with but little evidence in support of the supposition.

Round the head of the Gulf of Carpentaria, and down its eastern shores to Endeavour Straits, is a low, sandy, and utterly desert tract, traversed by a few salt-water creeks, but with little or no fresh water ordinarily flowing into their heads. Neither Dr. Leichardt nor Captain Stokes saw anything but an apparently illimitable plain stretching into the interior, south of the Gulf of Carpentaria.

I have spoken frequently of the dry and arid character of Australia. It is necessary to say a word or two of Australian lakes and rivers. Under ordinary circumstances, lakes and rivers in Australia are not at all to be supposed necessarily to have any water in them. They are mere hollows, depressions, or channels, where water *may be* occasionally after heavy rain. Lake George, in New South Wales, is commonly occupied by several fine farms. In the singular great horseshoe-shaped depression of Lake Torrens, in South Australia, you will see in one of Arrowsmith's maps, "There appears to be water in the centre of the lake." Mr. Eyre, in fact, rode eight or ten miles into the lake without finding water, but only soft, swampy, muddy ground, which got wetter as he proceeded, till he at last could go no farther. His calling it a lake was quite understood in Australia, and Captain Sturt speaks of it likewise as a lake; but it was the cause of some severe, but quite undeserved, animadversions in the "Athenæum," at the time of the appearance of Mr. Eyre's book.

In the same way the rivers—though, like other rivers,

winding through their valleys, with well-defined banks and cliffs—are, for the most part, mere dry water-courses, full of sand and gravel, with pools of water occurring occasionally, and, perhaps, a little trickling stream running or oozing from one to the other. Sometimes one of these pools or water-holes will be several hundred yards long, occupying the whole bed of the river, with deep, clear water, winding in steady reaches, and apparently bank full, when suddenly it ends quite abruptly, and the bed of the river beyond is covered by grass and bushes. It is as if a number of people, having set to work to deepen the river-bed in several places at once, had dug down a considerable depth and carried on their work for different distances and then all suddenly left off, the intermediate spaces remaining untouched, and the excavation they had made had then absorbed all the water and left the remainder dry. This very extraordinary character is not confined to any one portion of the country or to any kind of river, but is common to the smallest "creek" or brook, and the largest river, such as the Darling, to the water-courses of New South Wales, Victoria, and Van Dieman's Land, and to South and Western and Northern Australia. The only exception seems to be the River Murray and the rivers that, rising on the Australian Alps, are fed by their melting snows, and thus supplied with water enough to keep up a perpetual stream.

It very often happens, also, that some of these water-holes are salt, sometimes as strong as brine, while others immediately adjacent are quite fresh. This is the case, too, with wells, the water of one well will be undrinkable

from its saline and aluminous flavour, while another within less than a hundred yards will be beautifully fresh and pure.

We come now to the auriferous character of Australia. Sir R. Murchison, in his address to the Geographical Society in 1844, alluded to the possibly auriferous character of the Great Eastern Chain of Australia, being led thereto by his knowledge of the auriferous chain of the Ural, and by his examination of Count Strzelecki's specimens, maps, and sections. Some of Sir R. Murchison's observations having found their way to the Australian papers, a Mr. Smith, at that time engaged in some iron works at Berrima, was induced by them in the year 1849 to search for gold, and he found it. He sent the gold to the Colonial Government, and offered to disclose its locality on payment of 500*l.* The governor, however, not putting full faith in the statement, and being, moreover, unwilling to encourage a gold fever without sufficient reason, declined to grant the sum, but offered, if Mr. Smith would mention the locality, and the discovery was found to be valuable, to reward him accordingly. Very unwisely, as it turns out, Mr. Smith did not accept this offer; and it remained for Mr. Hargraves, who came with the prestige of his Californian experience, to re-make the discovery, and to get the reward from Government on their own conditions.

This first discovery was made in the banks of the Summer Hill Creek and the Lewis Ponds River, small streams which run from the northern flank of the Conobalas down to the Macquarrie. The gold was found in

the sand and gravel accumulated, especially on the inside of the bends of the brook, and at the junction of the two water-courses, where the stream of each would be often checked by the other. It was coarse gold, showing its parent site to be at no great distance, and probably in the quartz veins traversing the metamorphic rocks of the Conobalas. Mr. Stutchbury, the Government geologist, reported on the truth of the discovery, and shortly afterwards found gold in several other localities, especially on the banks of the Turon, some distance north-east of the Conobalas. This was a much wider and more open valley than the Summer Hill Creek, and the gold accordingly was much finer, occurring in small scales and flakes. It was, however, more regularly and equably distributed through the soil, so that a man might reckon with the greater certainty on the quantity his daily labour would return him. At the head of the Turon River, among the dark glens and gullies in which it collects its head waters, in the flanks of the Blue Mountains, the gold got "coarser," occurring in larger lumps or nuggetts, but these being more sparingly scattered. The reason of these circumstances, which are common to all auriferous regions, has been given in the former part of this Lecture when speaking of the power of moving water.*

* In many newspaper accounts and letters received from the diggings, the gold is described as having been evidently in a *state of fusion;* this is in all probability quite a mistake. Its having been deposited in small holes, crevices, and interstices of the quartz rock, and subsequently rolled, and perhaps partially discoloured on the surface, so that it assumes such forms as melted lead is seen to do, probably gave rise to the notion.

With the subsequent history of the "gold diggings" of Australia, the discovery of many rich auriferous districts, both in New South Wales and Victoria, you must all be more or less familiar.

In Mr. Arrowsmith's map, appended to the Parliamentary Report just issued, all the auriferous spots are marked in yellow. They occur at intervals along the flanks of the Great Eastern Chain, or on its lateral spurs and subordinate ranges through an extent of country about one thousand miles in length, about as far as from London to Gibraltar or the confines of Turkey, or as from London to Iceland in a straight line. The principal localities marked on this map are Grafton Range and Burnet River, north of the Condamine; Stanley Creek and Canning Downs in the Moreton Bay district; several spots in the neighbourhood of Liverpool Plains; the Turon and Conobalas on the Macquarrie, below Bathurst; the Abercrombie River at the head of the Lachlan; some spots on each side of Breadalbane Plains; the Braidwood and Araluen diggings in the Shoalhaven district; Lake Eimeo in the Australian Alps; and Ballarat and Mount Alexander and Mount Blackwood, north-west of Port Phillip.

In every one of these localities granite and metamorphic rocks occur, and quartz veins are frequently spoken of. This is an important fact to bear in mind.

In scarcely any of them do we find mention made of the gold being seen in the actual rock, but in the drift clay, sand, and gravel, or lying loose on the surface of the ground. The hundredweight of gold, indeed, found by Dr. Ker north of Bathurst, is described as a block of

highly auriferous quartz, lying among a lot of other loose blocks, evidently derived from a broad quartz vein running up the hill behind them. Such a mass, indeed, could hardly be transported far from its original site by any conceivable current of water.

The superficial drift in which the diggings have been carried on varies in thickness from a few inches to twenty or thirty feet. The following is an extract from a Lecture given by a Mr. Gibbon, in Melbourne, and reported in the "Melbourne Argus," giving an account of the Ballarat diggings:—"On the surface of the earth was turf, in a layer of about a foot thick, below which was a layer of rich black alluvial soil, and below that grey clay; below that again was a description of red gravel, which was sometimes very good; then red or yellow clay in which gold was found; and then a stratum, varying in thickness, of clay streaked with various colours, and scarcely worth working; and the next stratum was of hard white pipe-clay, which was a decided barrier. Immediately above it, however, was a thin layer of chocolate-coloured clay, tough and soapy. This was the celebrated blue clay, and was very rich."

"The ground on which the diggings were situated was a sloping bank. The blue clay is found near the surface on the brow of the hill, that is, at the depth of about a foot; but it is sometimes necessary to dig twenty feet before arriving at it."

Mr. Latrobe, Governor of Victoria, describes the Ballarat diggings as carried on through,—

"1. Red ferruginous earth and gravel.

"2. Streaked yellowish and red clay.

"3. Quartz gravels of moderate size.

"4. Large quartz pebbles and boulders; masses of ironstone set in very compact clay, hard to work.

"5. Blue and white clay.

"6. Pipe-clay.

"In some workings the pipe-clay may be reached at the depth of ten or twelve feet, in others not at thirty and upwards."*

To enter farther into the details of the several diggings would be alike tedious and useless. I must refer you for them to the two Parliamentary Reports published, the one in February and the other in June, and to the many small publications with which the shops are now swarming.†

My object to-night has been to give you such a rough sketch of the geology of Australia, and of the geological facts and principles that ought to guide any one in his search after gold, as may be of use to those intending to emigrate there.

In conclusion, I may perhaps be allowed to utter one word of advice.

Gold-digging is very hard work—just such work as you see navigators at in a railway cutting, or brick-makers in a brick-pit. You must work hard all day, lie hard all

* "Parliamentary Report," June 14th, 1852.

† At the instance of Mr. Latrobe a geological survey of the province of Victoria has been determined on, my late colleague in the geological survey of Great Britain, Mr. A. R. C. Selwyn, having been appointed to the office of geologist.

night, with but little shelter, often with scanty food, and with nothing of what you have probably been accustomed to consider necessary comfort. If you find you have no luck at the diggings, or if your health, or strength, or resolution fail you, do not, therefore, give up or despond altogether. You go out *to dig for gold,* do not *be ashamed to dig for anything else.* I speak to those now who have been hitherto unaccustomed to manual labour. Recollect it is the *avowed object of your voyage,* and the only thing you have to trust to. If you fail to dig up gold, there are lands to be ploughed, sheep to be herded and sheared, cattle to be tended, corn to be sown and reaped: every one of these fully as honourable occupations as digging for gold. Go, then, with a bold and resolute heart, determined to get your own living by the strength of your own arms and the sweat of your own brows; and be assured, that industry and perseverance lead to fortune in Australia with fewer impediments and uncertainties in the way than in any part of the world.

LECTURE II.

OUR KNOWLEDGE OF AUSTRALIAN ROCKS AS DERIVED FROM THEIR ORGANIC REMAINS.

BY

EDWARD FORBES, F.R.S.

PROFESSOR OF NATURAL HISTORY IN THE GOVERNMENT SCHOOL OF MINES, AND OF BOTANY IN KING'S COLLEGE, LONDON.

EDWARD FORBES, F.R.S.,

ON

OUR KNOWLEDGE OF AUSTRALIAN ROCKS AS DERIVED FROM THEIR ORGANIC REMAINS.

Of the six lectures constituting this course mine has least concern with the main theme—Gold. That precious substance is neither the object nor, excepting in rare cases, the reward of natural-history labours. My duties in connexion with the Museum of Practical Geology have reference entirely to the organic world as it existed during the long-past geological epoch, a world in which gold plays no part. My discourse, therefore, must be like the play of Hamlet with the part of the hero omitted. Yet, as even in that great drama, there are scenes in which only subordinate characters appear, necessary to the understanding of the plot, so in a course of lectures upon the chief among metals there must be one at least devoted to the making clear of collateral geological questions, of some consequence to the searcher for gold and the settler in Australia.

Intending emigrants frequently inquire how they may get some knowledge of geology, such as might be useful

to them in the country to which they are bound. To all who have the time I would strongly recommend the reading of some elementary work of geology in connexion with an examination of the collections of fossils, displayed in stratigraphical order in the galleries of the Museum of Practical Geology. By doing so they may at least familiarise the eye with the general aspect of the characteristic organic remains of different geological epochs. Although the specimens there arranged are British, they really constitute a key to the geology of the world.

That a knowledge of the meaning and leading bearings of fossils is of consequence to the emigrant may be plainly shown by referring to those books and guides which profess to give some geological information. In most of these, terms are used such as *palæozoic*, *secondary*, and *tertiary*, which mean nothing without an acquaintance with the comparative ages of organic remains. They are words founded upon considerations connected with the fossils contained in the rocks so styled. In the matter of gold it is often said that this substance is found in the *newest tertiaries*, or in connexion with *palæozoic* mountain-chains, whilst no explanation is given of what is meant by these terms, or how the reader is to distinguish between a tertiary and palæozoic rock when he sees them. I think it is possible for any person, even though uninstructed in geology, to attain some knowledge respecting these distinctions. Moreover, it does not concern gold merely, but, since the gold-seeker, whether he be fortunate or disappointed, is likely to acquire a taste for mineral observation, it is well that he should learn those elements of the sub-

ject that may serve him when he takes to soberer pursuits or when he settles in a colony. To pretend to teach even a small amount of natural history in a single lecture would be absurd. But so much may be taught as may prove useful by affording some insight into the mode of distinguishing between formations by their organic contents. This process, as applied to Australia, is the chief subject of this discourse, which is supplementary to the general account of the geology and physical geography of that country.

My object in this lecture is to give a brief and popular view of the classification of Australian rocks, as determined from the examination of the organic remains contained in them; to state in plain and untechnical language the grounds upon which we draw conclusions respecting their relative antiquity; to lay down some simple rules for recognising the fossils which afford the best clue towards the discovery of their ages; and to indicate the bearing of these conclusions upon the gold-searching and other practical questions. I cannot speak from personal knowledge of Australian strata. I have never been in the country, and have derived my acquaintance with this subject mainly from the accounts of Australian geology drawn up by competent observers, and from examination of collections of Australian fossils brought to England by able explorers. We have a fine collection of this kind in the Museum of Practical Geology, chiefly consisting of the original specimens described or noticed in that valuable work, the "Physical Description of New South Wales and Van Dieman's Land," by Count Strzelecki. The re-

searches made by that gentleman, the collections sent home by Sir Thomas Mitchell, those brought to England by my colleague Mr. Jukes, the personal observations of Mr. Darwin, the American geologist Mr. Dana, and the Rev. W. D. Clarke, the valuable essays upon Australian fossils by Professor Owen, Mr. Lonsdale, Mr. Morris, Mr. Sowerby, and Professor M'Coy, have furnished ample data upon which to base a fair notice of the characters of Australian rock-formations as exhibited in their fossils.

On this side of the world geologists recognise three great groups of stratified rocks, called *palæozoic, mesozoic* or *secondary*, and *tertiary*. The first term is applied to the oldest fossiliferous rocks,—such as the slates of Wales, the mountain limestone of Derbyshire, the coal-measures of the north of England. Next in order of age comes the second group,—such as the lias of Lyme, the oolites of Bath and Portland, the chalk of Kent. Newest, and above all the others, are the successive members of the third group,—such as the clay upon which London stands, the crag of Suffolk and Norfolk, the escars of Ireland, and the till of Scotland. As each of the instances thus indicated differs in age from the others, it will be understood that each great group has within itself many subdivisions. Now each of the groups, whether great or subordinate, is distinguished by the prevalence of certain kinds of fossils. These fossils are remains of creatures that lived when these formations were deposited in the condition of sediment either subsiding in a sea, or, it might be, in some instances, in a lake, marsh, or river. We know from examination and comparison of these fossils that there have

been numerous creations of entirely distinct assemblages of organised beings during the time when the world was in a manner being prepared for the advent and for the operations of man. And we have learned by experience to recognise the peculiar aspects of the fossils which distinguish one epoch in time from another. All over the world an instructed geologist is able, after a brief examination, to pronounce upon the probable age of a rock provided it contain fossil remains. Once having found such a rock, and ascertained its date, he is furnished with a key to the probable age of the strata which lie beneath it, or crop out from under it, and of those which lie upon it.

Of the three great classes of rocks (the term *rock,* be it observed, as used by geologists, has no reference to the hardness or softness of a stratum) the first and third are distinctly recognisable in Australia. That there are both *palæozoic* and *tertiary* strata in that vast country abundantly developed, is now quite certain. It is not clear, indeed it is very doubtful, whether there be any *secondary* rocks there, although, as we shall presently see, some important Australian strata are believed by certain geologists to belong to that class. Others, and I am inclined to agree with them, doubt not only whether we have any evidence of the existence of Australian secondary rocks, but also whether there ever were such strata formed within the present area of Australia; in other words, we hold that, not improbably, Australia was in the condition of dry land during the long ages when the oolites and chalk strata of Europe were in course of deposition.

In order to give a useful view of the relative ages and fossil characters of Australian strata, I shall now attempt a classification of them in descending order, *i. e.* taking the newest first, and going downwards, as it were, to the oldest. But it must be borne in mind that at the surface of the soil you may as readily have an old rock as a new one, though never a new rock beneath an old one, except in the rare case of some convulsive overthrow. Beginning at the very newest, we have, first:

I.

A. *Rocks now in process of formation.*—These occur wherever we have a rising of the land going on; a common occurrence, for the land, geologically speaking, is more unstable than the sea, rising in one place and sinking in another, though slowly and imperceptibly. New rocks are forming in the neighbourhood of the coral reefs, and in many places round the coast. In all these new-made strata the imbedded organic remains are of the same genera and species with creatures that are now living. Rocks of this class are of little consequence to the settler, although very interesting to the scientific observer. In King George's Sound and other localities are rocks which appear to have been formed out of blown sand, and which contain concretions probably resulting from included stems of plants.

II.

B. *Superficial Drifts and Bone-breccias.*—A great part of the north of Europe and of North America is covered here

and there, sometimes over large expanses of land, by accumulations of sand, gravel, and clay, evidently of recent date as compared with the strata upon which they rest, but older than modern alluvium, as is plainly demonstrated by the remains of different assemblages of animals, and here and there of extinct creatures found in them in not a few localities. In the northern hemisphere the contents of the greater part of this drift indicate the prevalence of a cold climate during its deposition. In strata connected with it, either below and immediately preceding it, or above and intervening between the drift epoch and the present, are often found remains of remarkable extinct quadrupeds, such as the elephant, tiger, hyena, hippopotamus, and others not now living in Europe, and belonging to species of those animals not now found alive at all. There is a parallel phenomenon in Australia. In alluvial deposits on the Condamine river, westward of Moreton Bay, there are found bones of extinct quadrupeds, and an ossiferous *breccia*, or angular pudding-stone, in caves explored by Sir Thomas Mitchell, in Wellington Valley, 210 miles west of Sydney. At the sources and on the banks of the Macquarrie are similar bones, all testifying to the former existence of a distinct race of quadrupeds from that now living in these regions. The minute examination of these bones made by Professor Owen brings to light the interesting fact that all these extinct creatures, though differing as species, and some of them generically, from those now inhabiting Australia, were formed on the same extraordinary plan, being marsupial animals, kangaroos, wombats, and quadrupeds allied to the opossum, though many

of them were gigantic in comparison with their relatives now living.

It appears extremely probable that the drifts, or accumulations of water-worn detritus, in which gold has been found in such abundance, are to be classed with tertiaries of the epoch of these extinct animals. This is distinctly the case, as has been shown by Sir Roderick Murchison in Russia, and you have already been told how he anticipated from geological analogies the probability of the discovery of gold in Australia. The Rev. W. B. Clarke, that active and enterprising geologist, now residing in Australia, states that the "bone caverns and unsepulchred relics of the gigantic *diprotodon* and *nototherium*, are in the auriferous rocks and detritus of Australia." In California gigantic fossil bones are reported to have been found in the gold-bearing drifts. The mere presence, however, of such organic remains in a drift is not necessarily an indication of the likelihood of finding gold there. Other conditions are requisite for the fulfilling of this result. It is in drift in the immediate neighbourhood, and on the flanks of ancient mountain-chains, disturbed palæozoic rocks, that we should look for the precious metals, whilst at the same time the presence of the bones in question may afford a good indication that it is the right kind of drift we are exploring.

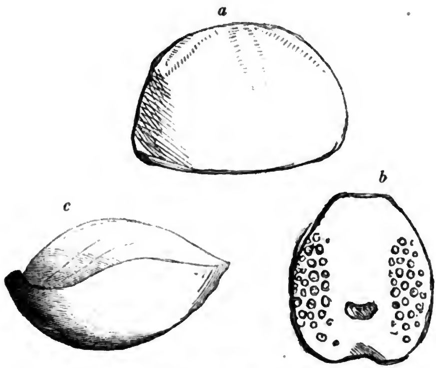
In Van Dieman's Land there is a yellow limestone at Hobart Town remarkable for containing extinct land-shells, and kinds of snails not now known in the colony. At Franklin's Village, in the same island, sea-shells were found in muddy sand at a depth of 140 feet, about fifteen miles from the sea, that were different from those resem-

bling existing Australian kinds. There is reason for thinking that these beds are of more recent date than the next to be noticed, and that they may possibly be of the age of the gigantic kangaroos and wombats, or at any rate of the date of the commencement of that epoch. In Van Dieman's Land also beautiful preserved trunks of silicified trees are met with, the tissues of which exhibit all their minute structure under the microscope. Near Hobart Town there is found a deposit of travertin containing impressions of the leaves of plants: these were collected by Mr. Darwin, and examined by Mr. Robert Brown, the most illustrious of living botanists, and the man who first opened out to science the richness and singularity of the Australian flora. But none of these relics of plants were recognised by him as identical with, or even closely resembling, existing Tasmanian kinds. One of the leaves resembled in shape that of a fan-palm, and no plants with leaves so constructed now grow in Van Dieman's Land.

III.

C. *The older Australian Tertiaries.*—In the work of Count Strzelecki there is a figure of a fossil shell called *Terebratula compta*, from Port Fairy, near the south-east corner of New Holland, "associated with casts of *Nucula, Lucina*," and other species of shells, "in an elevated beach." I have received the same shell from inland strata on the banks of the Murray, where it is found along with numerous other shell-fish and fossil sea-urchins of undescribed species. The same formation has been noticed

by several observers, especially by Captain Sturt, as extensively diffused in Southern Australia, and considerable collections are contained in the museums in England, taken from these beds. On the map of the gold districts in Australia, constructed by Mr. Arrowsmith, you will see "oyster-shells" marked in places, but far away from the gold. These localities are on this old tertiary. Among a considerable number of shells brought from Melbourne, I recognise species of *Ostrea, Tellina, Venus, Leda, Lucina,*



FOSSILS OF AUSTRALIAN TERTIARIES.

a. Echinolampas. *b.* Spatangus. *c.* Terebratula Compta.

Pecten, Modiola, and *Cerithium,* all shell-fish, but all kinds appearing to be different from living sorts. There are also sea-urchins of several kinds, all very different from any that I know of now living in the seas around New Holland. These fossil sea-urchins belong to the genera *Echinolampas, Brissus, Spatangus, Echinus,* and *Scutella.*

Having in the course of my examination of the productions of the Australian seas, carefully and extensively collected in many localities from Port Dalrymple to Cape York, during the surveying voyage of H. M. ship *Rattlesnake,* under the late lamented Capt. Owen Stanley, R.N., and also of much of the collections made by Mr. Jukes during Captain Blackwood's voyage, acquired a knowledge of the *Echinoderms* and shell-fish of this part of the world, I can speak personally with much confidence respecting the probable age of the Australian tertiaries placed under this third head. I believe them to be much older than they have hitherto been considered, and so far as we can compare them with European strata, to be probably the equivalent of middle (or miocene) tertiaries. In many respects these fossils bear a striking resemblance to those characteristic of the miocene strata of the Mediterranean, a likeness especially indicated by the forms and characters of the sea-urchins, which in this case, as at Malta and Corsica, are the best preserved of the relics. This similarity is dependent partly upon the presence of species of genera which are now extinct. Their contrast with the prevailing kinds of the same sets of animals now inhabiting the coasts of Australia is very striking, whilst at the same time there is a sufficient affinity to indicate the truly tertiary character of the wide-spread formation in which they occur.

IV.

D. *The Sydney Sandstone.*—This extensive formation, occupying very considerable areas in New South Wales,

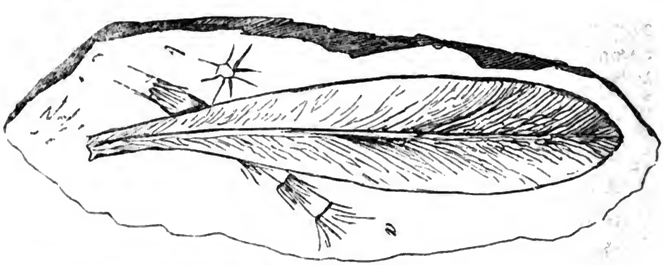
and in places being as much as 1400 feet in thickness, consisting of soft, yellowish and reddish sandstones, passing into conglomerates above, and sometimes into argillaceous slates below, is undistinguished by organic remains, though in all probability of marine origin. A few vegetable impressions, traces of coal, and remains of fossil trees, have been noticed. The strata are usually horizontal. It is believed by all its describers to pass into, and be in distinct connexion with, the coal-formation underneath it. It makes a barren and unproductive region, "a world of stone quarries and sterility, or desert plains of red sand," as Sir Thomas Mitchell has strongly, but apparently with great truth, stigmatised it.

V.

E. In the *coal-bearing strata,* said to flank the Australian and Tasmanian Cordilleras for 1200 miles, underlying the Sydney sandstone, and consisting of sandstones and shales, separating seams of coal, abundance of organic remains have been found. These are almost all of vegetable origin; but, in two or three instances, remains of fossil fishes have occurred. In consequence, chiefly, of the researches of Professor Agassiz, the geological relations of extinct tribes and genera of fishes are so well known, and have proved to be so constant, that the discovery of relics of these animals is of no small importance in a scientific point of view. The fishes which have been found—one of them is figured and described by Mr. Dana—belong to palæozoic types; and may be paralleled by forms known to be characteristic of the uppermost portion of the car-

boniferous system in the northern hemisphere. This is very significant, since the evidence of age yielded by the fossil vegetables of these beds would rather indicate that they are members of the secondary series of rocks, and that they may be compared with our oolites. In the old coal-measures of Europe and North America curious furrowed, scored, and fretted stems of vegetables, called *Calamites, Sigillaria,* and *Lepidodendron,* mostly very different from any plants now existing, are found in great abundance. But, although the Rev. W. B. Clarke has stated that he has found fossils referrible to these kinds in Australia, none has ever been brought to Europe which can fairly be considered as such. I have seen the supposed *Lepidodendron* mentioned in the list of rock specimens printed in one of the recently-issued Government blue-books, and can safely say that it is very doubtful, and, in all probability, nothing of the kind. Nor will Mr. Jukes, who has been quoted as having observed these fossils in Australia, admit that he had seen any distinct instances. On the other hand, the coal-plants of the coal-fields in New South Wales and Van Dieman's Land bear a striking resemblance to those of Burdwan in India, and to those of the carbonaceous shales of oolitic age in Yorkshire. As, according to our present experience, the greatest supplies of coal are furnished by strata of the upper palæozoic group, this question about the age of the Australian coal-bearing strata becomes of economic interest. Mr. Morris and Mr. Dana incline to the belief, that during the epoch called *carboniferous,* when the great coal-bearing beds were deposited, the vegetation of the

New-Holland area differed materially from that of the northern hemisphere, and may have assumed that aspect which we associate with the notion of an oolitic type in Europe. Mr. M'Coy, on the other hand, in his valuable and well-illustrated memoir on the Australian fossils, contained in the Woodwardian Museum at Cambridge, regards these coal-plants of New Holland as oolitic, and the beds containing them as of much newer age than those below. But all competent observers who have examined the strata on the spot, especially Mr. Jukes, Mr. Clarke, and Mr. Dana, assure us, that the beds pass into each other, and are not only *conformable*—*i. e.* lying on and parallel to the beds below—but also evidently *in sequence, i. e.* deposited without the intervention of a long interval of time. The peculiar fossil fish, already alluded to, supports this view, to which, after consideration of the arguments on both sides, I certainly incline; and would, therefore, set down the coal-fields of Australia and Van Dieman's Land as formations of the carboniferous sections of the palæozoic era,—which, in other words, means as equivalents of the most productive coal-fields of the northern hemisphere.



GLOSSOPTERIS BROWNIANA AND PHYLLOTHECA, AUSTRALIAN COAL-PLANTS.

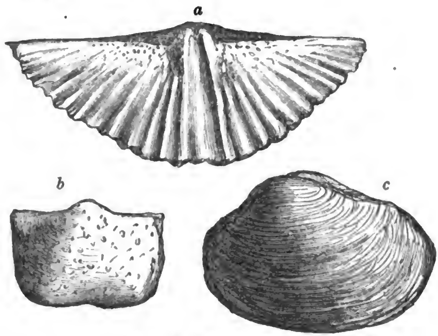
The fossil plants of the Australian coal-shales are often beautifully preserved, and owing to being black, or very dark, on a ground of lilac shale, make very elegant specimens. Most of them are small ferns, chiefly simple-leaved kinds, mingled with plants resembling the *Equisetum,* or mare's tail of our wet meadows, and remains of trees of the pine tribe. The mare's tail-like plants belong to the *Phyllotheca Australis,* and have a foliage arranged in wheels, that recalls the aspect of the pretty *Asterophyllites* of our English coal flora. The commonest and most characteristic of the Australian coal-plants is the fern called *Glossopteris Browniana.* In its combination of reticulate veins with a simple frond, it differs from any palæozoic European ferns. Portions of large trees are not uncommon in these coal-measures, all allied to the pine, as can easily be determined by an examination of their microscopic structure. You will observe, that in this region, where we might expect to find remains of gigantic tree-ferns especially prevailing in a fossil state, none has been certainly made out. During the epoch of the deposition of these coal-beds in Australia this province was, probably, in the condition of low swampy land, where the vegetable remains were accumulated and preserved in lagoons, to which they were conveyed by floods. This notion of their origin is supported by the fact of their containing no marine remains.

VI.

F. *Beds containing Upper Palæozoic Shells and Corals.*—All over the world we are enabled to recognise

palæozoic strata by their peculiar animal contents. The shapes of the shells of the corals contained in them are admirable guides. They include so many peculiar forms of ancient life that we cannot easily go astray about them. Now below the coal strata in Australia there are grey and red, very clayey sandstones, with limey concretions, that contain fossil shells in great abundance and perfection. There are but few remains of plants in them, but such as occur are remains of coniferous stems, similar to those in the coal-beds. The shells and corals have been thoroughly examined, described, and figured. Attention was, I believe, first called to them and to the epoch they indicated by Dr. Buckland, when describing Mr. Oxley's collections, and afterwards by Dr. Fitton, in his appendix to Captain King's "Researches." They are very interesting in a natural-history point of view, and of some value as affording indications of good soil. Several of them, such as those called *Spirifer glabra, calcarata,* and *attenuata,* are exactly identical with kinds that are characteristic of upper palæozoic limestones in Europe. Along with these are others, especially the bivalve shells called *Pachydomus, Eurydesma, Astartilia,* &c., which have never been met with in rocks of any other part of the world. Many of them are large and conspicuous. For practical purposes the *Spirifers* are perhaps most serviceable. These are bivalves, somewhat resembling cockles, but easily distinguished by their unequal valves, one of which has a fold and the other a depression down the centre, whilst there is a more or less developed area or triangular flattened space between the beaks at their backs. When they are perfect two spiral

arms are found coiled up in their interiors, hence their name. The abundance and variety of these shells and the presence of *Productus,* another bivalve (the upper lid of which is like a closed fist, and often rough with spines or scale-like markings, and the under valve flat or concave), are good clues to the age of the rocks in which they occur. The very large swollen smoothish bivalves, like inflated river-mussels found in these Australian rocks, are kinds of *Pachydomus.* As the valves of these shells are found usually united and undisturbed, and in some places swarms of a kind are congregated together, it is surmised that they were suddenly destroyed. Univalve shells of peculiar types occur along with them; these are mostly allied to the *Trochi,* or top-shells.



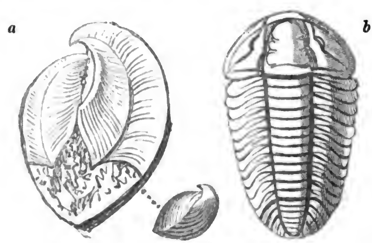
UPPER PALÆOZOIC FOSSILS.

a Spirifer. *b* Productus. *c* Pachydomus.

VII.

G. *Older Palæozoic, or Silurian Rocks.*—These, the oldest rocks preserved to us with their organic contents,

are now known with certainty to occur in Australia; strata containing their characteristic fossils, having been found there by the Rev. W. D. Clarke, who announces a rich harvest of specimens and species, few of which have, however, yet been seen in England, so that we cannot say with certainty how far the majority correspond with those of the northern hemisphere. Yarralumba, Yass Plains, and Burragood, are recorded Silurian localities. Among the best clues to the recognition of the older palæozoic rocks, by means of their fossils, are the abundance and *variety* of the remains of *Trilobites*. These curious bodies are the relics of ancient crustacea, or animals of the crab tribe, but wholly different from any now existing, and not known in the fossil state in any strata that are not palæozoic. Moreover, in the upper palæozoic rocks, the genera and species of trilobites are few; in the lower, very numerous. They may be recognised by their jointed



LOWER PALÆOZOIC OR SILURIAN FOSSILS.
a Pentamerus. *b* The Trilobite called Calymene.

bodies, furrowed by two longitudinal grooves, so as to divide them into three parts, a middle and two side-lobes, terminated at one end by a three-lobed head, and at the

other by a tail marked with a central axis and sulcated sides. The *Calymene,* or Dudley trilobite, is found in the Silurian strata of Australia, just as in Europe. Very characteristic shells and corals also mark the Silurian system.

VIII.

H. Beneath the lower palæozoic beds we have *metamorphic rocks,* such as mica slate, gneiss, supposed to be stratified rocks changed by actions, whose nature is a matter of discussion. Whatever the change has been caused by, the result is, that all traces of organic remains are obliterated. In these rocks gems occur, and it is in them we should look particularly for precious stones of various kinds. They rest upon rocks of igneous origin; but these last are not necessarily older, for we find them often sending jets and veins into the stratified rocks above them, which, whenever it occurs, is a proof of their being of newer date.

In rocks of igneous origin, of which there are many and varied sorts in Australia, no fossils are found except in those rare cases where animal or vegetable bodies have become invested in a stream of lava or overwhelmed by a volcanic shower.

In this brief enumeration of the fossiliferous strata of Australia, I have not attempted to describe their extension and boundaries. Those features of the geology of this island-continent are sketched by Mr. Jukes, and indicated in the map which he has constructed. They are admirably laid down in the great map of New South Wales and Van Dieman's Land, constructed by Count Strzelecki,

deposited in this Museum. But we have much yet to learn respecting the geology of even the best explored parts of these countries; and if any of my audience visit unexamined districts, they will do a service to science by carefully collecting and noting the relative positions of the fossils, bones, shells, or corals that they may find in the rocks or soil.

I shall now briefly call your attention to the connexion between the fossiliferous rocks noticed and matters of economical interest.

I. *Gold.*—I have already said that this metal is found either in connexion with palæozoic rocks, or in tertiary drifts of a very recent epoch, yet of anterior origin to the general physical features, and appearance of the animals and plants now indigenous to Australia. Of the mineral character of these rocks and drifts as presented in that country, it is not for me to speak: indeed, a far better notion of it than I could possibly give, you can obtain by perusing any documents on the subject signed by Mr. Stutchbury or Mr. Clarke; and there are several papers by those gentlemen among the documents respecting discovery of gold in Australia, ordered to be printed by Parliament. I mention their names only, because being able geologists their observations and descriptions of the rocks which they have personally explored are more precise and valuable than those written by persons unacquainted with geology. Bear this in mind about gold, that it is useless to waste your time in searching for it in the older tertiaries, or in secondary rocks, though none of the latter appearing to be as yet discovered in Australia, you are not likely to go

wrong through them. The *older* palæozoic, the metamorphic rocks, that lie beneath them, and the *newest* tertiaries, all taken in connexion with mountain chains, are our best guides in this matter.

II. *Coal.*—It may possibly be of some use to remind you of the signs of coal, that this valuable substance is of organic origin, and consists of vegetable matter. Also, that it has been found most abundantly and valuable in connexion with the *upper palæozoic* rocks. In places where no coal is seen, its presence may be indicated by traces of characteristic coal plants on the layers of stone In Australia, for example, the tongue-shaped fossil fern, name *Glossopteris Browniana,* and of which I have given a woodcut, would be regarded as a certain indication of carboniferous strata, and finding fragments of stone with such and similar fossil impressions, might indicate to you the neighbourhood of coal-bearing rocks in a district in which no coal had hitherto been discovered. But though coal is found in some quantity here and there over the world in tertiary strata, as a general rule tertiary districts are very unproductive of this valuable mineral. Yet much good gold has been thrown away, in vain searches after coal in districts so constituted, where no geologist would have thought of wasting his money for an instant. A caution on this point may be of value, and it may also be well to say, that every strong sandstone is not a coal-measure sandstone, and every blue limestone not a carboniferous limestone; the fossils only in the absence of clear evidences of superposition, can enlighten you on this point.

III. *Settling on Land.*—It would appear that the

geological character of the soil is worthy of the consideration of the settler when he chooses land. The Australian tertiaries do not carry many recommendations, unless in the neighbourhood of older strata, and of eruptive rocks in a decomposing condition. Of the older Australian rocks, the Sydney sandstone is agreed to be barren and unproductive. The shell-containing palæozoic strata, on the other hand, are attractive to the agriculturist. If this prove to be the rule, as would seem not improbable, the observation of the character of fossils in a rock may afford some useful and profitable hints to the man who is seeking where to pitch his tent for life. As a rule, districts where the foundation is a rock abounding in fossils, provided other conditions be equal, are to be preferred to those constituted of unfossiliferous formations. This will apply to many countries besides Australia. The frequently disturbed condition of the older fossiliferous strata aids in promoting their agricultural value. In all cases, however, the mineral constitution of the rock itself, and the presence or absence of superficial drift, should be carefully regarded and constitute elements of the calculation.

IV. *Diamonds.*—As these precious bodies are probably of vegetable origin (a notion long ago held by Sir Isaac Newton and rendered still more likely by the researches of Sir David Brewster), and possibly even a crystallised gum, I may fairly claim them as fossils, and, therefore, coming under my dominion. I am anxious to call attention to the chance of their being discovered in Australia and likelihood of being overlooked. Some time ago Mr. Tennant, who has kindly permitted me to exhibit

these specimens illustrative of the condition in which diamonds might be expected to be found, urged the search for them upon persons going to gold regions, especially California, reminding us of their great comparative value, diamonds in their rough state being worth about 50*l.* an ounce. They have been found associated with gold in several parts of the world, as in Brazil and Russia, and in similar drift, especially in the ferruginous concretions of pebbles forming the beds of rivers running through the gold-drifts. But in seeking for them you must not mistake every glittering and transparent crystal for a diamond. These may be "Bristol diamonds" or "Irish diamonds," but are sorry substitutes for precious stones. This morning I saw one of these glittering crystals of quartz picked up in California by an unlucky adventurer, who refused 260*l.* for it there, and brought it to England to learn that it was worthless. Had he known that diamonds

a Quartz-crystal. *b* Diamond-crystal.

never assume the form of a six-sided prism, with six-sided pyramids at its ends, he would not have built castles in the air upon this imaginary jewel. Look for crystals that are eight-sided, such as are two four-sided pyramids, for example, joined base to base. In this shape, and in the form of cubes and dodecahedrons, true diamonds occur. Do not trust to file or hardness. Mr. Tennant, who has much practical knowledge on this matter, has sent forth

some valuable warnings about the danger of such rude methods of treating diamonds, which are really very brittle gems, and may sometimes be broken more easily than quartz.

Diamonds are reported to occur in a rock called *Itacolumite,* a quartzy micacious schist, and this is often said to be their parent rock. They are also said to occur in soft micacious sandstones. Rocks very similar to those which enjoy the reputation of being diamond-containers occur in Australia. The *Itacolumite* itself is a metamorphic rock. I do not anticipate success in a search for the diamond in the rock which might be its matrix, but mention these facts as confirmatory of the chances of our yet finding the diamond in Australia. Other gems may occur, but they do not come within my province, being of a truly mineral and not of an organic origin.

Throughout this lecture I have been advocating the study, even superficially, of fossil remains on purely economical grounds, in the hope that some knowledge of them may prove useful to those who would seek fortune, comfort, and competence in a distant land. I would not have done so did I not conscientiously believe that information of this kind is of value to my hearers. But I should scarcely feel that I had done my duty unless I urged upon your attention the study of natural history, in any or all its various branches, for less utilitarian reasons. To those who are about to settle in the colonies I would urge, most earnestly, whilst they seek to benefit their bodies, not to forget the culture of their minds. I would urge them to remember that reason is the grand gift of God to man,

and that the noblest use of wealth and best blessings of comfort are the enabling us, freed from harassing struggles and cares, to cultivate that reason. It might be that you will find yourselves away from books, away from all sources of public instruction, even away from the cheering sound of human converse. How, then, are you to cultivate the gift divine of intelligence? Easily and everywhere. There was no spot in the world where the book of nature is not spread open—full of interest—free for every man's perusal. When the emigrant's hard day's labour is over, and he rests upon the grass, or the rock, or the mountain-side, or on the plain, or on the sea-shore, let him waste no time in repining thoughts or idle longings, but let him look at the flower, or any living or dead creature that may be near him, the being that lives now and the relics of that which lived myriads of years before man enlivened those wilds; let him observe the exquisite beauty of its conformation, the skill displayed in the construction of its several parts, the superhuman wisdom and care evinced by the adaptations of its structure, and cheerfully and firmly believe that the Divine Presence thus manifested among the insignificant denizens of the solitude will not forget him.

List of the principal Works in which Descriptions and Figures of Ausralian Fossils are contained.

Three Expeditions into the Interior of Eastern Australia. By Major T. L. Mitchell, Surveyor-General. London, Boone, 1838.

In this work are contained figures of the bones found fossil in the caves at Wellington Valley, and descriptions of them by Professor Owen. Also figures of some upper palæozoic fossil shells, with descriptions by Mr. G. B. Sowerby.

Geological Observations on the Volcanic Islands, visited during the Voyage of H.M.S. Beagle; together with some brief Notices on the Geology of Australia and the Cape of Good Hope. By Charles Darwin, M.A. F.R.S. London, Smith, Elder, and Co., 1844.

In the appendix to this volume are descriptions by Mr. George Sowerby of palæozoic shells from Van Dieman's Land. There are no figures.

Physical Description of New South Wales and Van Dieman's Land. By P. E. de Strzelecki. London, Longman and Co., 1845.

There is much information about Australian fossils of various ages in this valuable book, with full descriptions of them by Professor Owen, Mr. Morris, Mr. Lonsdale, and Mr. G. B. Sowerby. There are many excellent figures of the species described.

On the Fossil Botany and Zoology of the Rocks associated with the Coal of Australia. By Frederick M'Coy. A series of papers contained in the "Annals of Natural History" for 1847 (Vol. XX. of the First Series). London, R. Taylor.

This is a highly valuable and abundantly illustrated memoir, and contains a full account of the large collection of specimens sent by the Rev. W. B. Clarke to Professor Sedgwick, and now contained in the Woodwardian Museum, at Cambridge.

Geology of the United States' Exploring Expedition under Commodore Wilkes. By James D. Dana. New York, Putnam (no date, but published in 1848 or 49).

In this important volume there is much original information concerning the geology of New South Wales, and descriptions and figures of numerous palæozoic fossils.

The above works should be consulted in connexion with Mr. Jukes' "Account of the Physical Structure of Australia."

LECTURE III.

ON THE CHEMICAL PROPERTIES OF GOLD, AND ON THE MODE OF DISTINGUISHING IT FROM OTHER SUBSTANCES RESEMBLING IT.

BY

LYON PLAYFAIR, C.B. F.R.S.

PROFESSOR OF CHEMISTRY, GOVERNMENT SCHOOL OF MINES.

DR. LYON PLAYFAIR

ON

THE CHEMICAL PROPERTIES OF GOLD.

It is important for intending Emigrants to the Gold Regions to possess such knowledge, with respect to the chemical characters of gold, as may enable them to recognise its presence, even when its quantity is too small to be visible to the eye. It is a matter of every-day occurrence for chemists and mineralogists to have brought to them glittering substances resembling gold, often obtained at great expense and with much labour, and which generally resolve themselves into iron and copper pyrites or yellow mica. A small amount of knowledge would have prevented the disappointment usually attending such mistakes, for the characters of gold are well marked and incapable of being confounded with those of other metals when they have once been learned.

It will be my duty to point out in plain and simple terms the methods of distinguishing gold by what chemists term the "wet way;" as it will be that of my colleague, Dr. Percy, to explain to you the metallurgical

processes for obtaining gold in the "dry way." At the same time it will be desirable to direct your attention to the properties of some other precious metals which may occur to you in your search after gold; and also to point out the means by which you may readily distinguish those substances which are so frequently mistaken for the noble metal.

Gold has justly been considered the noblest of metals from various physical and chemical properties. It is unchangeable in air, and does not rust like iron, copper, and other ignoble metals. It is of a bright reddish yellow colour when in a coherent state, and is very dense. It is highly malleable, or, in other words, it may be beaten into thin leaves of a thickness not greater than the $\frac{1}{282000}$th of an inch. A single grain of gold may be beaten into a leaf which will cover $56\frac{3}{4}$ inches, and may be drawn out into a wire 500 feet in length.

Gold requires a strong heat to melt it, the temperature necessary for that purpose being about 2840° Fahr.; and when melted it is almost fixed in the fire, though if placed in the focus of a burning mirror, it gilds a silver leaf hung over it, thus showing that it is converted into vapour to a small extent.

It has already been mentioned that the colour of gold in its coherent state is of a reddish yellow colour. When, however, it is in a fine state of division, this colour is not observed. Gold precipitated in a metallic state from solutions is blue when diffused through water and examined by *transmitted* light; but if allowed to settle, it is brown by *reflected* light. If gold-leaf be examined in a

strong light, by allowing the rays to pass through it, the colour is found to be sometimes green and sometimes blue.

The density or specific gravity of gold is so characteristic of this noble metal, that it is important you should be able to determine this for yourself. The term "specific gravity" means the relative weight of *equal bulks* of different substances, their weight being generally referred to water taken as unity. Thus, if we suppose one cubic inch of water to weigh 1, then a cubic inch of silver would weigh 10·4, a cubic inch of quicksilver would weigh 13·5, and a cubic inch of gold 19·3. Gold has, therefore, a very high specific gravity, being nearly 19½ times heavier than the same bulk of water. It is obvious, therefore, that the determination of this point is an important means for its recognition. The mode of obtaining a specific gravity is very easy, and simply consists in ascertaining accurately its weight in air and then immersing it in water and weighing it again. In water it will be found to weigh less than it did in air, and this loss in weight is exactly equal to a bulk of water precisely the same as the bulk of gold weighed. To obtain the specific gravity of the specimen, you have to divide the original weight in air by the *loss* of weight in the water, and the result is the specific gravity. I make the following experiment roughly to show you how to proceed. I tie a horse-hair round a sovereign, and hanging it to the bottom of the pan of a balance weigh it in air. A tumbler of water is now brought below it, and the sovereign is immersed in the water and as it now weighs considerably

less, the weights in the opposite pan are removed until the balance is restored. The following are the records of the experiment—

	Grains.
Weight of the soveregn in air	123·25
Weight of the sovereign in water	116·35
Loss in weight	6·90

Now, to obtain the specific gravity, I have only to divide the first number 123·25, by the loss in weight 6·90, and the result 17·86 is the specific gravity of the sovereign as ascertained by this rough experiment. This is not pure gold, but a mixture of gold with other metals, and weighs therefore less than the same bulk of pure gold. It is possible even to calculate from the specific gravity of an auriferous quartz how much pure gold is contained in it; and as this knowledge is important I give the necessary formula in a note, although it is much more complex than the former.*

Having thus alluded to some of the more prominent physical properties of gold, we must now examine some of its more important chemical characters. But it would be

* If the weight of metal = M and the $\frac{\text{density of metal}}{\text{density of water}} = m$,

Weight of rock = R and the $\frac{\text{density of rock}}{\text{density of water}} = r$,

Weight of rock and metal = W,

Apparent weight of rock and metal in water = Q,

Then

$$M = \frac{m\,[\,W - r\,(W - Q)\,]}{m - r}$$

$$R = \frac{r\,[\,m\,(W - Q) - W\,]}{m - r}$$

obviously useless to describe to you the refinements of chemical testing, or to show you processes which could only be successfully performed with all the resources of a well-appointed laboratory. I prefer, therefore, to describe to you methods of detection which you may use with materials easily derivable from any druggist's shop. Gold is not attacked or dissolved by aqua fortis (nitric acid), or by spirits of salt (muriatic acid), when they are separate, but it readily dissolves when a mixture of these acids is heated with it. This depends on the circumstance that chlorine is formed by the mutual action of these acids, and that element is the proper solvent for gold. The mixture of nitric and muriatic acids is called *aqua regia*, from its power to dissolve gold. It is possible that you may not be able to procure nitric acid, and in that case, if you throw bleaching powder into water containing the gold, then add spirits of salt, and heat the mixture gently, the gold will be dissolved by the chlorine evolved. Even if spirits of salt are unattainable, then by throwing some common salt and saltpetre into water, and then adding a little oil of vitriol, chlorine will be produced, and the gold will dissolve. Alum may be substituted for the oil of vitriol, but not with advantage. In all these cases you must use either glass or earthenware vessels, and the substance supposed to contain gold should be ground to a fine powder.

Having dissolved the gold by any of the means above mentioned, we have now to examine its chemical behaviour to various tests. It is, however, necessary to add to the solution some carbonate of soda, in order nearly to neu-

tralise the excess of acid before we apply the tests. To the solution of gold we add a solution of *green vitriol* (sulphate of iron), and immediately you observe that a brown precipitate is formed; this is metallic gold in a very fine state of division. If the solution be mixed with a considerable quantity of water, the liquid on the addition of the green vitriol is coloured brown by reflected light, and blue by transmitted light, and this is obvious even when 40,000 parts of the liquid are present; if the liquid amount to 80,000 parts, it is coloured sky-blue; with 160,000 parts, it becomes violet; with 320,000 parts of liquid, the violet tint is still very obvious; but with 640,000 parts it is with difficulty perceived.

To another portion of the solution we add a solution of salts of tin, and you observe that in the mixture we have a purple or reddish brown precipitate known as the *purple of cassius*. The exact shade of colours obtained depends upon the extent to which the solution is diluted, but the test is equally sensitive with that just described.

Some organic compounds precipitate gold readily, and are very useful in recognising its presence; but care must be taken that no free nitro-hydrochloric acid is present. For this purpose, an excess of carbonate of soda should be added, and then the organic acid, until it tastes distinctly sour. Thus if to a portion of the solution we add oxalic acid, and heat the mixture, the gold is thrown down as a brownish powder, or, in certain circumstances, in the form of a soft, yellow, spongy mass. A Seidlitz powder may be used instead of oxalic acid, and when the mixture is

boiled the gold is precipitated in the form of a nearly black powder.

Gold has a powerful affinity for mercury or quicksilver, and readily unites with it. If the gold be in the state of fine powder, or of scales, an excess of quicksilver readily licks it up, forming an *amalgam*. This property is used by the metallurgist to remove gold in circumstances in which mere washing would not be sufficient. When the compound or amalgam of gold and mercury is obtained, it is easy again to separate them, because mercury being volatile, is driven off by the application of heat, leaving behind the gold in a pure state. One of the processes of gilding depends upon this circumstance. You will find that this behaviour of mercury to gold receives important applications, as will be described in the succeeding lectures.

I shall return to the consideration of the mode of testing auriferous quartz when it is presented to you; but before doing so it may be useful to refer to the chemical properties of some other metals, which are not uncommonly associated with gold.

The first to which I refer is silver, a metal readily distinguished in its separate state by its colour and other physical properties, and easily enough recognised by its chemical behaviour to reagents. Silver is usually of a white colour, but when in a very fine state of division it is of a dark grey. It is harder than gold, but softer than copper, and being very malleable may be beat into thin leaves, and from its tenacity may be drawn into fine wires. It melts at a lower heat than gold, and in the fused state absorbs oxygen, which escapes on cooling and produces the

spitting as the metal solidifies. The specific gravity of silver is only 10·4, or about one-half that of gold, and its proper solvents are nitric acid or sulphuric acid. The former acid dissolves it readily, forming nitrate of silver or lunar caustic. Oil of vitriol (sulphuric acid) dissolves silver when heated with it, and this solvent is used to refine gold containing silver,—the latter dissolving while the former remains unattacked. Certain proportions between the metals are required for their effectual separation. When the silver is dissolved by the oil of vitriol, a few fragments of copper suffice for precipitating it from the solution, and it may thus be readily detected. If a solution of common salt or of muriatic acid be added to a diluted solution of the silver salt, a curdy white precipitate (chloride of silver) is formed, and this is peculiarly characteristic of this metal. The chloride of silver is soluble in ammonia, and may thus be distinguished from many other white precipitates. The precipitate may further be tested by putting it into a crucible with carbonate of soda, and exposing the mixture to a strong red heat, when a button of pure silver will be obtained.

Platinum is another metal frequently associated with gold. Platinum is of a light steel grey colour, but is one of the noble metals, and ranks in price between gold and silver. After these two bodies it may be considered the most ductile of the metals, although it is more tenacious than them, and will support greater weights on equal thicknesses of wire than any metal except iron or copper. The specific gravity is about 21·5, and is therefore greater than that of gold. It is very infusible,

and does not melt by itself in the strongest heat of a forge. Platinum, like gold, requires a mixture of nitric and muriatic acid to dissolve it; neither of these acids attacking it when separate. The various solvents already described under gold will equally act upon platinum, although less readily. These properties render this metal of great value in the chemical arts; and large stills, costing several thousand pounds, are used in the sulphuric acid manufactures. Platinum, when dissolved, and the acid neutralised by carbonate of soda, is deposited as a black powder if the mixture be boiled with a Seidlitz powder (or with tartaric acid and soda). The addition of sal ammoniac and spirits of wine to a strong solution of platinum causes the deposition of a yellow crystalline precipitate, characteristic of this metal. Oxalic acid does not precipitate platinum as it does gold. It is very desirable that those who go to the Gold Regions should look well for this precious metal, as it is likely to escape the notice of the common observer from its less glittering appearance.

I have now to call your attention for a few moments to the substances lying before me, and which from their yellow colour and shining appearance have been frequently mistaken for gold. The first of these is yellow mica, a light substance of small specific gravity, and having none of the properties of gold. The specimen which I hold in my hand was part of a cargo brought from the Arkansas in mistake for gold, the adventurer being nearly ruined by his ignorance. Some time since, when one of my colleagues resided at a sea-port town, a ship arrived from Ichaboe having as part of its cargo a number of bags of

supposed gold. This "gold,"—in reality yellow mica,—had been found on the surface and swept up by brooms into bags, in which it was preserved as a great treasure. Two dealers in the precious metals went to examine it, and one prudently brought a portion in the evening to my colleague to assay. The other, hoping to steal a march on his fellow-trader, went on board and bought the whole lot in the middle of the night, at a high price, the material being utterly worthless in a commercial point of view, and not containing a grain of gold.

You observe on the table this elegant mahogany box, with its secure lock and Government seal. This box was forwarded to this institution only a few days since, and was supposed to contain specimens from a newly-discovered gold region in one of our neighbouring islands. The specimens are in reality only iron pyrites, so often mistaken by novices for the precious metal. As this is one of the most common mistakes, I now proceed to describe how you may distinguish iron pyrites from gold by very simple means. If you took its specific gravity, all doubt would vanish,—or even an examination of its hardness would dispel the illusion, for a scale of gold would readily be taken up on the point of a needle, while iron pyrites is too hard to be thus seized. If you throw a little pyrites on a shovel and heat it over the fire, the smell of sulphur will be very obvious, and the yellow compound will be gradually roasted to the colour of red iron rust. You may put a piece upon a bright shilling, and heat it over the flame of a lamp, when the smell of sulphur may be perceived, and the silver will be tarnished. To satisfy

yourself further, you may dissolve a little of the suspected mineral in muriatic acid, to which you have added a few drops of nitric acid; and then the solution will give iron rust on the addition of ammonia, a black ink on the addition of an infusion of nutgalls, or a bright prussian blue on adding prussiate of potash. After these tests no doubt could be entertained that the metal under examination was iron, and not gold. It does, however, sometimes happen that iron pyrites is gold-bearing, although the amount of the noble metal is so small as to require a practised hand for its detection. Iron pyrites occurs abundantly in this country, and it would scarcely be a profitable speculation to send it home. Copper pyrites, however, is equally mistaken for gold, and is much more valuable as a mineral than iron pyrites. It may be roasted like the former, and leaves a reddish-black ash, exhaling the smell of sulphur. If dissolved in acids it gives characteristic actions, which render the presence of copper easily distinguishable. Clean iron, such as parts of an iron hoop, or clean iron nails, thrown into the solution, cause the precipitation of copper. This experiment, apparently showing the conversion of iron into copper, deceived the alchemists in their researches, and gave much support to the idea that one metal may be transmuted into the other. The action depends, however, upon a simple exchange, the iron going into the solution, in proportion as the copper goes out. In some districts, it is customary to economise the copper from streams passing over copper pyrites; which, by percolating it, oxidise and convert it into sulphate of copper, from which copper

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is extracted by throwing in pieces of old iron into the stream. Besides the metallic deposition of copper, by means of iron, the chemical tests are very decisive, and lead to the ready detection of copper when existing in solutions. Ammonia added in excess, that is, until the solution smells strongly of it, precipitates any iron which may be present in the form of iron rust; but keeps copper in solution, communicating to the liquid a deep blue colour. Prussiate of potash, added to the copper solutions, produces a mahogany brown precipitate, even when the quantity of metal is present in very small quantity. Carbonate of soda precipitates copper in the form of an apple-green compound. Copper ore in the latter form exists abundantly in Australia, and is sent over to this country with great profit, being smelted in South Wales.

It may be useful to recapitulate, and to give in a tabular form more precise reactions for the different metals to which we have alluded, because these may be useful to those who are enabled to obtain the reagents referred to, although some of them may be unattainable under ordinary circumstances in the Gold Regions.

Tests for Gold.

Tests or Reagents.	Results.
Green vitriol (sulphate of iron)	In acid solution, brown precipitate; if very dilute solution, only a blue colouring.
Salts of tin (protochloride of tin)	In dilute solution, a purple red colouring; when strong, almost brown precipitate.

Tests for Gold—*continued.*

Tests of Reagents.	Results.
Metallic zinc	Precipitates metallic gold as a voluminous brown precipitate.
Potash (in excess) . . .	No precipitate; after some time a green colouring and slight precipitate.
Ammonia	Yellow precipitate (fulminating gold).
Carbonate of soda, or carbonate of potash	No precipitate in cold solutions, but when heated voluminous precipitate like oxide of iron.
Bicarbonates of soda or potash	No precipitate.
Carbonate of ammonia . .	Behaves like ammonia, carbonic acid being evolved.
Oxalic acid	Dark, greenish black precipitate, more quickly produced by heat.
Tartaric acid and soda . .	Dark precipitate when boiled.
Sulphide of ammonium and sulphuretted hydrogen .	Dark brown or black precipitate.

These reactions are so characteristic that it is impossible to mistake gold for any other metal. The tests most easily applied by persons unaccustomed to chemical manipulation are sulphate of iron, salts of tin, and oxalic acid.

The following table gives the general tests for silver:—

Tests for Silver.

Tests or Reagents.	Results.
Potash	Brown precipitate, becomes black on boiling.
Ammonia	Brown precipitate, soluble in excess of ammonia.
Carbonate of soda or potash .	White precipitate, soluble in ammonia.
Carbonate of ammonia . .	White precipitate, soluble in excess of reagent.
Phosphate of soda . . .	Yellow precipitate, soluble in ammonia.

Tests for Silver—*continued.*

Tests of Reagents.	Results.
Oxalic acid	In neutral solutions white precipitate.
Sulphuretted hydrogen and sulphide of ammonium . .	Black precipitate.
Muriatic acid or common salt .	White curdy precipitate, soluble in ammonia.
Zinc or copper	Precipitates white metallic silver.
Sulphate of iron	In neutral solutions white metallic silver.

The most easily applied of these reagents is the solution of common salt, which gives a curdy white precipitate, easily recognised by its solubility in ammonia. If the silver be dissolved in sulphuric acid, its precipitation by copper is very characteristic.

The following table gives the reactions of platinum:

Tests for Platinum.

Tests or Reagents.	Results.
Chloride of potassium or chloride of ammonium (sal-ammoniac)	Yellow crystalline precipitate produced readily by the addition of spirits of wine.
Potash or ammonia . .	With chloride of platinum acts like the chlorides of potassium and ammonium.
Carbonates of potash and ammonia	In chloride solution yellow precipitate.
Carbonate of soda . . .	No precipitate.
Sulphate of iron . . .	No precipitate.
Oxalic acid	No precipitate.
Salts of tin (protochloride of tin)	Dark brown red colouring, no precipitate.
Sulphuretted hydrogen and sulphides	Dark brown nearly black precipitate.
Tartaric acid and soda . .	On boiling, metallic platinum falls as black precipitate.
Zinc	Slowly precipitates metallic platinum as black powder.

The most easy test is to take the solution of platinum in aqua regia and add to it carbonate of potash (pearl ashes) or ammonia, when the yellow precipitate will be observed; it appears more quickly on the addition of spirits of wine.

Having now described the properties of the different metals which it is desirable to look for as being frequently associated with gold, I may shortly describe to you how you should proceed with a mineral to be examined. Supposing you have auriferous quartz, reduce it to powder and boil for some time, in an earthenware or glass dish, with aqua regia. Pass the solution, after diluting it with water, through a filter, then allow it to cool, and add a solution of carbonate of soda until no more effervescence takes place. This precipitates all the other metals which may be present, except gold and platinum. Now filter from the former, and add a solution of oxalic acid until it does not cause effervescence and has a sour taste; then boil; if there be any gold present, it will be precipitated as a black powder. Throw, again, on a filter of blotting paper, add salts of tin, when a reddish brown colouring will appear if platinum be present. On the first filter mixed with the quartz, will be the silver, if any be present. Wash this with ammonia, and to the solution which comes through add muriatic acid until the smell of the ammonia disappears, and the silver will be thrown down as a white curdy precipitate.

The following plan may also be used. The solution in aqua regia should be concentrated by evaporation, until it is of small bulk. About three-fourths of its bulk of spirit

of wine should now be added, and then a saturated solution of sal-ammoniac. The platinum is thrown down as a yellow crystalline precipitate, while the solution filtered from this, and boiled with oxalic acid, deposits gold.

All the methods to which I have alluded are plans for detecting the precious metals by the wet way, and do not require to be used on all occasions, as my colleagues will fully explain to you the general indications for ascertaining their presence by mechanical devices or by the process of dry testing, which, in many respects, is the best adapted to the purposes of the miner.

I have now endeavoured to impart to you the means by which you may recognise gold in doubtful cases, and I trust that the knowledge may occasionally prove useful. You are now called upon by one of those eventful periods which have occurred in the history of many nations, to people a land infinitely fertile in resources, impelled by a desire to obtain wealth by pursuing its direct representative. The desire to attain gold, which caused so copious a stream of emigration from America to California, and now produces so large a flow from this country to Australia, is only the repetition of a desire which at all times in human history has exerted a most important influence in the advance of civilisation, and in the discovery and developement of neglected natural resources. This desire became the passionate madness of philosophers and nations for a thousand years, and has left its records in the history of alchemy. It passed over the world like an epidemic, leaving traces of its presence everywhere, though in some countries it became more deeply rooted,

and exerted greater influence on national character than in others.

The Arabians, when Bagdad, Bassora, and Damascus flourished as centres of commercial activity, hunted for gold by the labours of their philosophers, and kept up the desire for it by the reveries of their poets. Genii raised palaces of gold, and the fruit trees produced only the precious metal. Gems of wondrous price and treasures of the king of metals were the reward of their heroes and travellers, just at the time when bloody and cruel giants inhabited our own country, and when Scotland and Ireland were the scenes of fantastic tricks by capricious and fitful fairies. Then Germany revelled in her witches, who rode on broomsticks, and sprites, whose occupation it was ever to fill hogsheads with the purest wine; while the rivers of France ran beauteous nymphs, immortals easily wedded to mortality. But in all countries, one after the other, giants, dwarfs, witches, fairies, sprites, and nymphs, disappeared before the stern chase after gold. Chemistry recognises that her greatest discoveries arose in this pursuit, not *directly* but *indirectly*. The search after the transmutation of the baser metals into gold led to the discovery of a philosopher's stone very different from that which occupied the attention of the earlier alchemists.

In the answers which Nature gave to the ill-defined and impulsive questionings of the alchemists, were apparent that the true philosopher's stone consists not in the direct discovery of gold, but in the developement of Nature's laws, which enable us to add to the resources and happiness of the human race. The real philosopher's stone of the

alchemists was the science of chemistry created by their researches. By it we have learned to add immensely to our comforts and enjoyments. The earth now yields to us increased abundance in conditions where in absence of knowledge she would have proved unproductive. Metallic ores, formerly unworkable, are now reduced to metals absolutely requisite to our everyday comforts, more precious even than gold, and which enable us to join the remotest parts of the earth by bands of constant communication. All countries are now found to have resources of immense importance to an ever-increasing civilization, and the sciences which can render them productive are the true philosopher's stone, changing base materials into gold.

Depend upon it, then, your search after gold is, as it has always hitherto proved, a means by which civilisation will in the end be materially extended. But recollect that gold in itself is only an empirical representation of actual material wealth, which really consists in the full developement of all natural resources. The only true method to ensure wealth will be that you neglect not the gifts which God has placed at your disposal. The country to which you intend to emigrate is full of natural resources, still very slightly developed. In a more thorough developement of its agriculture, in the cultivation not only of wool and of tallow, but in the conversion of those nutritious parts of animals now thrown away into excellent and portable food, there is much wealth to be obtained. There are many minerals there, less luring than gold, but more certain in their return, and far more useful to the everyday comfort of mankind. Recollect, then, that while we

hail with pleasure, as all history justifies us in doing, the desire for gold which forces so strong a tide of emigration to Australia, that history also tells us, that the consequent good generally arises from collateral causes rather than from the one which produced the original impulse. Though disappointment will doubtless attend many of those who see only the philosopher's stone in the drifts and quartz of the Gold Regions, those who read God's teachings as displayed in Nature will find a more sure way of transmuting valueless materials into gold, by going out with the steady desire to improve and develope the natural resources of their adopted home, in the firm belief that success will attend their efforts, if they avail themselves of that knowledge of the Creator's works, which He has permitted His creatures to attain, with a view to advance their comfort and happiness in this world.

LECTURE IV.

ON THE DRESSING, OR MECHANICAL PREPARATION OF GOLD ORES.

BY

Wilkinson

WARINGTON W. SMYTH, M.A. F.G.S.

INSPECTOR OF MINES TO THE DUCHY OF CORNWALL.

WARINGTON W. SMYTH, M.A. F.G.S.,

ON THE

DRESSING, OR MECHANICAL PREPARATION OF GOLD ORES.

IN the history of the various nations of the earth, during those times of which any trustworthy accounts have been handed down to us, there never was a period at which the discoveries of gold followed each other in such quick succession, aroused so much attention throughout the civilised world, and were productive of such momentous results. And yet it will be advisable, preparatory to commencing the subject of which I propose to give you a sketch, to remind you of the descriptions of similar events, which may be gleaned from the records of past times, that you may be aware how much has been thought, written, and done on the same subject, and not imagine, with some, that the conditions under which the gold occurs are new, or that novel and crude ideas on the extraction of the precious metal are to be preferred to any past experience.

I will only recall to your attention, that in all probability, from tradition and early history, the discovery of

gold in the sand and gravel of streams would appear to have been the first step in the recognition of metals, and that, in almost all, perhaps in all, the countries of Europe, Africa, and Asia, greater or smaller quantities of gold have from very early times been washed by simple contrivances from the auriferous deposits. The old stories of Midas, and of the Argonauts and the Golden Fleece, the histories of Herodotus and Diodorus Siculus, the descriptive collections of Strabo and Pliny, all tell the same tale of the wide distribution and early utilisation of stream-gold; whilst the discovery of massive golden ornaments in the graves of early tribes, remote from the seats of Mediterranean civilisation, and in lands where little or no gold is now obtained, attests in a wider manner the same facts.

Occasionally, indeed, the success of the gold-streams has been great enough to produce a pulse of excitement which has vibrated for a while through a district, but has been hushed down again, to use the geologists' expression, both in time and space, or, in other words, has been soon forgotten from the want of printed description, and has not been transplanted to other countries, from the small facilities of communication in those days. Take, as an example, Bohemia, now producing no gold, but many of whose valleys strike the traveller with surprise, covered as they are with heaps of the upturned sand and silt of the river beds. In the year 760 the poor people turned out in numbers to wash gold from the river sands south of Prague, and three men were able in the day to extract a mark (half a pound) of gold; and so great was the consequent rush to "the diggings," that in the next year the

country was visited by famine.* We read of a recurrence of similar events several times within the next few centuries, although here, as elsewhere, the general attraction to surface-spread riches has subsided into regular and systematic mining.

From the early times of which I have spoken, to the present day, workings of this kind have been carried on continuously in some few countries, whilst in others tin ore has been extracted by methods very similar in their general features, from superficial deposits of precisely the same character; and as this latter class of work is extensively practised in our own country, it will be important to pay some attention to the mode of "streaming" in Cornwall and Devon.

With respect to the modes of occurrence of gold a good deal has already been told you by my colleagues; and I will only advert to those points which must guide us in the choice of some among the various processes for extraction. As the title of my lecture includes the *mining* of gold, I must remind you in the commencement, of the difference in the two classes of deposit in which that metal is found, the *lodes* or *veins*, which intersect the solid rock in a direction more or less perpendicular to the horizon; and the *drift-beds*, or "*streams*," in which the gold mingled with gravel, sand, or clay, has been deposited by the mechanical action of water, upon the surface of those rocks, which are penetrated to unknown depths by the lodes.

* Abhandlung von dem Alterthume des böhmischen Bergwerks, von M. G. Körner. Schneeberg, 1758.

To the former class belongs more specially the art of mining; to the latter the simple operations which our Transatlantic friends have aptly termed "diggins," although even in the latter, after the heavy commonplace labour of moving earth or stones, must be appended a certain degree of skill for the successful extraction of whatever precious particles have there been placed by natural causes.

It must be very clear to all present, that if I were requested to take twenty folio volumes, and read them through to you in the course of an hour, not even locomotive-engine speed could avail me; and thus, I must premise, is it equally impossible to attempt to bring before you any of the details of mining, or even of what I wish more particularly to dwell upon, the mechanical preparation of the ores; but in the same manner as I might read out to you the title-pages of those volumes, and give you a few words on their contents, so I hope to be able to lay before you something of interest and utility in describing the principles of the chief operations, and the action of some of the apparatus which has been employed.

Gold-mining, properly so called, is, like other mining, an art requiring the employment of capital, and of a skill only to be acquired by years of experience. There is no art practised by civilised man which requires for its full developement the application of so many sciences and collateral arts. But although so essential to the miner, scarcely any of these are necessary to the gold-washer or streamer, who must trust chiefly to the strength of his arm and the buoyancy of his health, albeit the occasions must

be many on which he would be greatly aided by some of those branches of knowledge to which I have alluded. The apparatus which he employs must necessarily be simple, so as to be conveyed from place to place, to be easily repaired if injured, and not to require any of those niceties of manipulation which would cause him to lose time in acquiring, for the sake perhaps of only small quantities to be saved from waste.

It is true that to render "streaming" successful on the large scale, where poor places must be taken into account with rich, and where we must deal more with the average, and less with the prizes, improved apparatus and arrangements must, as I shall presently show, be brought into play.

We must now suppose that you understand the nature of the drift-deposit of gold, best exemplified at the present day in Siberia, California, and Australia; and the difference between this comparatively ancient deposit, and the fine sands annually brought down by rivers, some of which are also found to contain gold in workable quantity. The latter are of course found literally at the surface, the former may be met with under a cover of from one to seventy feet in thickness,* consisting of soil, peat, sand, gravel, or generally any materials capable of being washed down by the waters. The modes of working the two must be identical in principle, although from the modern sand being generally fine and sharp, a modification must

* Seventy feet is the greatest thickness of cover yet met with in the Russian gold stream-works, at Krestowosdwischensk, in the Ural Mountains.

be made in apparatus intended for the other, mixed as it may be with clay, or with large boulders.

With respect to mining on the one hand, and digging on the other, I will therefore not enter into further detail; but since the nature of the subject allows it, and it may be useful to some among my auditors, I will consider the subject of the dressing and washing, or the mechanical manipulation of gold ores generally, including as well those derived from lodes as the lumps, and grains, and dust, to be obtained from the stream-deposits.

The nature of the subject allows it, because with some (here unimportant exceptions,) the gold occurs in both cases native, and is therefore for the most part to be separated from the other substances which accompany it by its greater specific gravity; or where necessary, this separation may in both cases be aided by taking advantage of the readiness with which gold amalgamates with quicksilver. The great point of difference is this, that for the stream-works Nature has pulled down the highest, proudest and richest parts of the lodes, and so triturated and washed up the materials, that the streamer has the heaviest part of the work already done for him; whilst the miner, who attacks the poorer, but more lasting, deep-going lodes, must aid himself with all the resources of an art so nice, that whilst an entire community may be seen in one place supported in prosperity by an ore of given produce, total loss and ruin may be seen in another to result from a treatment of a similar ore without due knowledge of principles and practice of the "dressing," or mechanical preparation.

The processes by which ores, whether of gold or other metallic minerals, are prepared for the metallurgist, may be divided into three heads, viz., the *washing*, the *trituration* or reduction in size, and the *separation* of the useful from the waste: whilst other operations, as riddling for the sorting by size, and amalgamation, may be superadded at various periods of the routine through which the ores have to pass.

We will devote a short space to the consideration of these three divisions before proceeding to the description of some of the apparatus employed for one or more of these purposes together in the dressing of gold more specially.

1st. The *washing* is necessary not only to clear off mud and dirt from the larger fragments, and to enable us by sight to recognise them; but to set free small particles of useful mineral which are enveloped in clay, and would be lost without a sufficient stirring in a stream of water.

It is evident that a very different amount of this operation will be required for ores or "stuff" from different localities; and the mode of applying it may also vary from a mere fall of water of a few inches in height, under which the fragments are moved to and fro, to a variety of apparatus by which manual labour is in great measure saved, and by which either a simple, or a compound sorting, is simultaneously effected.

Thus the first treatment of the small ore from the mine, as well as of the earth or sand from stream-works, is the pouring of water from a small height, either from a scoop or from a continuous supply, whilst the material is

raked to and fro over a grating or sieve, to separate the large lumps.

When it becomes desirable to separate the mixed ore and stone into several different sizes, the water carrying with it the fragments which have passed through the upper grating, is led over another placed a few inches lower, in which the orifices are smaller; then again similarly over a third, formed of wire net: again over a fourth, and perhaps a fifth and sixth, of punched iron or copper-plate: and thus a perfect assortment as regards size is obtained, although at the expense of a large amount of wages, since a boy must be placed at each of the gratings and sieves mentioned, to pick over the coarse stones which refuse to pass through his particular sieve.

Among the various means of effecting the same object with less manual labour, I may instance the inclined cylindrical sieves employed in some of the Russian gold-washings, one of which, lately constructed, may be seen at Mr. Walker's in the City Road; and which being made of strong sheet-iron, punched with round holes, and set in revolution about an axis, has the material tipped in at the upper end, and by aid of a continual flow of water allows the small to fall through into a sloping table beneath, whilst it pours out the large stones at the lower end of the cylinder; and thus works up a very large quantity in the day. Again, the annular sieve employed in some of the large Russian machines, where the earth is continually worked up by travelling knives, is better suited than the last to thick and tenacious deposits, and will be described presently. As a third example, I may point out to you

the conical sorting-drum of Mr. Rittinger of Schemnitz, in which, by a very simple arrangement, four different sizes are divided from one another, whilst, with the expenditure of 1¾ horse-power and the labour of two men, it operates upon as much as ten to fifteen tons of mixed ore and stones in twelve hours.

As regards the second division, the *trituration*, I need say but little, inasmuch as Nature has already played the part of the machinist for the gold-streamers. You must not however forget that, besides the pure gold and the waste, which it will be your object to separate the one from the other, there may probably occur (in some of the districts, at all events) large quantities of fragments of vein-stone or gangue, such as quartz, or other earthy mineral, containing gold in sufficient quantity to render it worth dressing. It may, therefore, be useful to enumerate to you the four chief modes of reducing in size prior to separation. The simplest method—that generally employed at small mines which have not the advantage of machinery, is to bruise down the ore by hand with a heavy flat piece of cast or wrought iron, attached to a short handle, and termed a *bucker*. With a material of moderate hardness, such as the generality of copper and lead ores, and where no large quantity has to be treated, this method may pass muster, but in other cases must be replaced by one of the two following:—

Where the ore is to be reduced to a medium small size, as from the size of beans to large grains of sand, the *crusher* or *grinder* is employed,—a machine almost peculiar to this country, and to be seen in its more complicated

aspect in the lead-mines of the north, in its simpler form in Cornwall and Wales. The principle is that of a pair of rollers of hard cast-iron, almost in contact and revolving towards the space between them into which the ore is thrown. They are worked by steam or water power, more rarely by windmills, or on a small scale by horse-power or by hand.

If, however, the valuable portions of the stone be extremely minute, as is most commonly the case with gold and tin ores, it is evident that a piece of spar as large as a pea may contain a particle of gold or tin ore as large as a pin's-head, which unless the whole is farther reduced in size will be totally lost. Here, then, come into play the *stamps*, where a range of massive beams, shod with heads of iron, and weighing each from three to eight hundredweights, are lifted up in a vertical direction and allowed to fall on the ore, which is enclosed in a trough, and rests on a hard foundation, either of beaten stone or of iron. The details of their construction, and for the mode of outlet of the stamped "stuff," are not to be understood, much less criticised, without long study; but one point in their action deserves to be particularly noted, as being one of the chief items on which success in this operation depends. If, as I have before mentioned, with an ore of a given character, the fragments are too large, it is clear that we may lose a large proportion of what we seek to obtain. If, on the other hand, we allow it to be stamped too small, the valuable substance is "stamped dead," or, in other words, brought down to such an infinitesimal size that it floats away with the water, and cannot by any artifice be suc-

cessfully caught. Take a large hammer and gently crack a nut with it, and you have an illustration of what a stamp-head ought to do: it ought, if possible, to crack the enveloping shell of stone and set free the kernel of metallic mineral unbroken.*

The fourth method of trituration includes the grinding very small by edge-rolls, by the Mexican *arrastras*, and in mortars, all of which are only applicable in exceptional cases, from the great loss that would result in dressing by aid of water where the whole is reduced to so fine a state of comminution.

We have now to cast a glance over the third and most difficult set of processes in the preparation of ores—the *separation*. The one principle which is to guide us all through is the difference of specific gravity between the valuable and the worthless substances, whence it will be clear that the heavier the metal we wish to save, and the lighter the waste, the more readily and completely will the operation be effected. Of the contrivances used for this purpose, though I must begin by saying that their name is Legion, I may give you a general idea by first explaining that their action depends either on the suspension of the fragments in water, and the consequent fall of the heaviest to the bottom first, or on the flow of a stream of water down an inclined plane, depositing the heavier par-

* This loss, as regards gold, is very much more serious than would be imagined, and is due, in great part, to that property, *malleability*, which enables us with such ease to distinguish it, by aid of a hammer-face or a penknife-point, from other yellow minerals, such as iron and copper pyrites, which, being *brittle*, cannot be hammered flat or cut.

ticles first, and carrying the lightest away with it to the lower end of the plane.

Among those in which the particles have to be suspended in water are the *jigging-machines,* so very rarely applicable to auriferous ores that I may overlook them here; and the *dolly-tub,* or *keeve,*—a tub of wood or iron containing water, into which the material is thrown with a shovel, and where it is kept in continual agitation either by the same shovel or by means of a spindle with vanes. The settlement of the heaviest portion, clean and to itself, is much assisted by occasional blows on the side of the vessel. The same principle has recently been proposed with certain modifications for the washing of auriferous sands.

Of the inclined planes over which the stream of water holding the particles in suspension is made to flow, it will be sufficient to point out to you a few of the principal classes. Among the most important to the gold-dresser are those fixed troughs which are intended by the roughness of their floor to catch the grains of gold as they pass; those used in Hungary are placed, several together, immediately below the stamps, and are eight feet long by sixteen inches broad, with a fall of twelve inches; their bottom is covered with pieces of coarse canvass, which are gathered up every two or three hours and carefully washed in a tub of clean water. Should they be left too long, a coating of slime forms upon them, and the gold will then slip away; and to obviate this defect, Mr. Hoffmann, of Ruszkberg, applied a long piece of canvass, passing over rolls at the head and foot of his trough or frame, rotating

like an endless chain against the current, and dipping underneath into a chest of water. The same method has been applied by Mr. Brunton to the "framing" of tin ores.

Sometimes, instead of canvass, the roughness of unplaned boards is found available, or scratches made with a sharp tool, or, again, grooves cut across the board, or, lastly, the skins of animals. All these modifications are, however, insufficient to do more than make the first step in the separation, and various others of the inclined planes must be employed in addition. One great division of these is built of considerable depth, in order to allow the accumulation of the orey material for several hours together, after which it is dug out with a shovel to be further treated elsewhere. These are the "buddles" and "tyes" of English miners ("schaufel-heerd" of the Germans), and vary in form and quantity of water used according to the nature of the materials to be handled. The other class is allowed to be covered only by a very thin deposit, which is then delicately stroked on the surface by a wooden hoe or a besom, or by a gentle flow of water; and when sufficiently freed from slime is washed off into two or more receptacles for the various qualities of deposit, according as they are taken from near the "head" or the "tail" of the "frame." These tables, the "kehr-heerde" of the Germans, vary exceedingly in their construction and manipulation; and are sometimes, with great advantage, suspended in a peculiar manner by chains, and jerked by machinery at intervals against a block of wood.

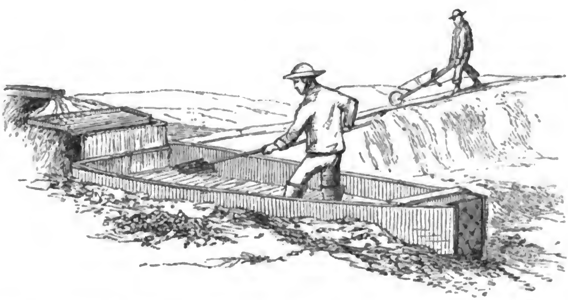
From the last-mentioned tables I am brought naturally

to the mention of the gold-washer's bowl, or vanning-dish, a little implement which affords the most simple method of separation on a small scale, and depends on the same principles as the above-mentioned moveable tables. It is constructed of some hard and close-grained wood, and varies in form in different districts, being circular in Brazil, and oval in parts of Transylvania and Hungary; whilst the size varies from three feet in diameter to small ovals of barely a foot in length, as used in Mexico. This bowl is used sometimes for actually washing auriferous alluvium, but can of course work but a limited quantity in a given time; more generally they are employed either as a means of assaying (like the "vanning" of tin on a shovel in Cornwall), or for the purpose of still further cleaning and separating the particles of gold as they are brought from some of the other concentrating processes.

A quantity of the material to be operated on having been mingled and well stirred by hand with water in the bowl, it is shaken from side to side and circularly, with a variety of movements suited to the form and to the nature of the ore, only to be acquired by long practice. The settlement and separation of the gold is partly assisted also by striking one end of the bowl occasionally so as to arrest the course of the particles for the moment; and, finally, several different layers or lines of mineral matter may be distinguished from one another, the gold occupying the lower position, then the magnetic iron, then the pyrites, and, lastly, other waste.

I may now proceed concisely to describe some of the apparatus which has been employed in various districts for

the combination of two, at least, of the principles of treatment which I have enumerated, and will commence with the extraction of stream-tin, since that process, so analogous to the extraction of gold from alluvial deposits, may be seen in action in Cornwall and Devon. Whilst ordinary labourers are occupied in removing the cover or "overburden," which contains no useful ore, the tinners at work on the "tin-ground," in the bottom, have put together a rough "tye," a wooden box somewhat like a coffin in



shape, nine feet long, two and a half feet deep, four feet wide at the upper, and eighteen inches at the lower end. One or more of the men are engaged in bringing barrow-loads of the material to be tipped into the head of the box or tye, over which a continual stream of water is flowing from a height of one and a half or two feet, and is so spread by the guidance of a piece of board as to fall in a thin sheet on the minerals beneath it, and thus to wash them thoroughly. At the same time, a second man is continually riddling out and picking the various larger frag-

ments and pebbles by fishing them up with a "prang," or grate of iron bars at the end of a shovel hilt. The large pieces are then picked over by hand, long practice enabling the tinner at the first glance of his eye to detect whatever is worth saving; and the stream of water, flowing with the smaller grains along the bottom of the box, is constantly separating the tin ore from the other substances, leaving it accumulated near the "head," whilst the others are carried down towards the "tail" of the tye. A subsequent cleaning is effected in a very similar tye, when the material is first washed under a preparatory fall of water on a head-board or box before it falls into the body of the tye, which is here of greater length.

To the simplest contrivances for gold-washing belong those employed in Transylvania, chiefly by the gipsies. A board of six or seven feet in length, and with a number of notches or grooves cut across it, is placed in an inclined position, or a similar board is covered with rough cloths, or two or three shorter grooved boards are placed in a series; and the auriferous sand, mingled with water, is made to flow evenly downwards from the top, whilst the metallic particles, caught in the grooves or in the cloth, are afterwards concentrated in the separating-bowl. Very similar is the mode practised on the Rhine, whose sands contain in a part of its course a small proportion of gold. An open box, with a wicker bottom, to act as a sieve, is set on trestles near the river-side, often on the very sandbank which is to be worked for gold, and an inclined board of a few feet in length, covered with loose rough cloth, is

so placed as to catch all the drippings through the sieve caused by the continual pouring of water with a scoop over the sand which is thrown into the box. Every now and then the cloths are taken up, and all the material adhering to them washed into a bucket of clean water; and, lastly, once a-week, the precious metal is amalgamated with quicksilver by aid of a sort of separating-bowl suspended by cords from the ceiling of a room.

In the remarkable work of Agricola, on Mining, published three hundred years ago, are descriptions and drawings of a variety of apparatus for the extraction of gold and tin ore, to one of which I must draw your attention. The "stuff," or sand and gravel, is thrown into a rectangular box, the bottom of which is formed of a perforated plate, and being well stirred by hand, the coarser portions are raked out on one side, whilst the finer fall through with a stream of water into a wooden canal or tye, some eight feet in length, divided into a number of compartments by slats or flaps of wood easily removed at pleasure. The sediment, therefore, fills one of these compartments after another, the richest occupying the cells at the upper end, the poorest being at the lower, and the contents of each are separately removed to be farther concentrated in the small washing-bowl.

This latter implement is represented in Agricola's spirited cuts as of various forms, often blackened on the interior, in order the better to show the grains of gold, and sometimes of larger size, to allow of the washing of a large quantity of sand by this means alone. Of these

some were suspended by strings, whilst others were used floating on the water, by a person standing in the stream, who dexterously, by aid of handles, agitated the sand and water in its cavity, much as before described when the bowl is held in the hand.*

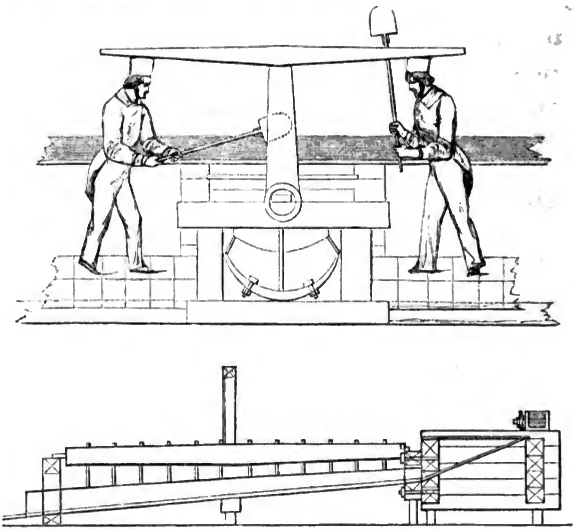
Very similar to the above described tye used by the Moravians in the time of Agricola, is the "cradle" introduced from Virginia and Carolina into California, and thence to Australia. This, however, instead of being fixed, is mounted on rockers, so that by means of a handle it may be swayed to and fro, and its general construction is probably known to my auditors from the woodcuts of the *Illustrated London News*. The length is divided into partitions, the contents of each of which are afterwards concentrated separately in the bowl. A great deal of manual labour is required for the cradle, since, besides those who feed it with fresh material, and those who remove the waste from the lower end, one man must continually (according to the usual practice) pour on water with a scoop, and another gives the rocking motion with one hand, whilst with the other he stirs up the fresh-brought "stuff" on the sieve, breaks up the clods, if tenacious, and occasionally loosens the sediment forming in the tye, when it becomes too firm. There can be no doubt, that by this method the loss of fine gold is very great; and in some cases the length of the divided tye has

* In Sir John Pettus's "Laws of Art and Nature," published in 1683, is a description of gold-washing, and of some very useful apparatus for the purpose, translated from the German of Lazarus Ercker.

been increased with a view to retaining some of what would otherwise be lost; but the disadvantage then follows, that the whole machine becomes too heavy for one man to handle, and also requires too much attention to keep the sediment stirred. The simplest proof of the rude working of the cradle is the fact, that already, in California, some of the sand has been operated upon a second, and even a third, time with advantage. In a few instances in the United States some quicksilver has been placed in a few of the upper partitions, to aid in arresting the gold; whilst at the point of exit a slip of gold rubbed over with quicksilver was fixed, to catch the stray particles on their way to the "wild flood."

Let me now say a few words on the machines used in Siberia, the chief constituent parts of which are much the same, viz., a sieve and a long tye with partitions, but where the sediment in the latter is continually worked to and fro by claws or scratchers. In the smaller apparatus, at which eight or ten men may be employed, the sieve or grating, firmly fixed, is 3½ feet square. The tye, into which the fine sand is carried by an inclined plane, is 16 feet long by 2½ feet wide, with an inclination varying according to the more or less loose nature of the sand, from 24 inches to 16 inches, and having its bottom curved in the arc of a circle. Above the tye, and placed in the direction of its length is a wooden axis turning on gudgeons, and having fixed to it in the under side as many arms as the tye has compartments, each of which arms is fitted with a number of claws or blunt knives; and by an alternating motion given to the axis by two men holding a lever attached to

it, the claws pass backwards and forwards in an arc, and keep the sediment in continual agitation.



The partitions in the bottom are ribs of 2 inches high and 2½ inches wide, held by screwbolts and nuts; and are removed every now and then for the washing out of the concentrated auriferous sand, the more frequently as the sands are richer in gold.

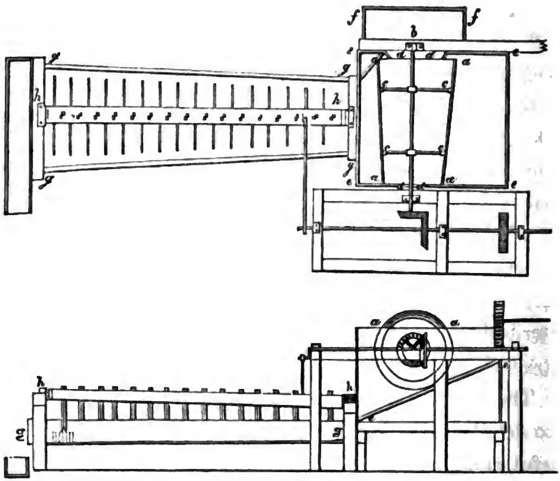
A great variety of machines have been proposed, one after another, at the Russian gold stream-works, but the principle of that just described appears to be most generally approved, and has been carried out on a much larger scale by aid of horse or steam-power. Four tyes, similar to that just described, are ranged two and two on opposite

sides of a large annular or ring-shaped sieve formed of plates of cast-iron perforated. In the centre of the ring stands vertically an axle, which is made to rotate, carrying several radiating arms fitted with knives, which keep passing round and round over the grating, tearing up and mixing together, all the various auriferous material which is tipped into the machine from above; whilst sufficient water for its dilution is poured on from jets led from a trough, or launder, carried round the sieve at a small height above. On each of two sides is a small square grating or picking table, at which a man continually rakes out the large stones which refuse to pass through the sieve, and throws what is useless into a waggon to be wheeled away. When the whole is set to work, the fine material falls through the sieve into an inclined plane, which leads it into the tyes, where it is continually agitated by stirrers, as before described, and whence the sediment is at last carefully extracted.

The limits of a lecture will not allow me to go farther into details respecting this or other machines; but it may be useful, at a time when so many ludicrous methods of washing auriferous deposits are proposed, to note that this Siberian machine is able to operate on 200 tons in a day, with the labour of eight horses, twenty men and six boys, including ten men for removing the waste, if in a level country without advantages for clearing it away. Yet it must be remembered, that to handle successfully an apparatus of this kind, where from the great scale of operation a small error must produce serious results, considerable skill ought to be possessed by the manager, proper discipline should

be maintainable among the work-people, to keep everything fairly going, and a sufficient extent of the gold-bearing drift must be within command, to warrant its first erection and regular action.

Another modification is the gold-washing apparatus by Agtè, in use at Alexandrowsk.



a a. Truncated cone of perforated sheet-iron, fixed by an iron frame, *c c*, to a horizontal axis, *b b*, which is made to revolve by a water-wheel about thirty times in a minute.

d d. The opening at which the cylinder is charged.

d′ d′. The opening at which the large pebbles roll out over the board, *f f.* Both these openings may be closed or opened at pleasure.

e e. Inclined plane, by which the sand which passes through the sieve is carried down to—

g g. The tye, or long trough, the plan of which is a truncated cone, and which has its bottom concave.

h h. The axis above the tye, to which are affixed arms carrying iron knives to stir the sediment, and making twenty to twenty-five oscillations per minute.

This apparatus, on the small scale represented, and employing four men for charging and for picking the pebbles, &c., will operate upon from twenty to forty tons in ten hours.

A very similar machine, called boudarui, has been used on the river Chapcha, having this difference in its arrangement, that the long axis of the sieve runs in the same direction as the tye.

Finally, in the choice of apparatus you must be guided chiefly by the following considerations:—1st. What is the quantity of soil and sand that it will operate upon, with an average quantity of water, in the course of a day? Some of the amateur inventors are apparently very little acquainted with sand or stone, tonwise. 2dly. That the whole material may be so efficiently stirred and broken when in clods as to prevent the loss of particles by their being enveloped in clay. 3dly. That the length be sufficient to prevent the loss of too great a proportion of finely comminuted gold. 4thly. That as few men as possible be required to work it.

All the apparatus described above will turn out the gold still so much mixed with other substances, as magnetic iron, pyrites, &c., that it requires to be further concentrated. The powder so obtained is commonly of a gray colour, and termed gray schlich; for its further cleaning it must be very delicately treated on one of the uncovered tables or frames of which I have before spoken. That used in Siberia is 7 to 10 feet long, by 3 or 4 feet broad, the inclination being variable according to circumstances. The frame is divided into an upper and lower

part by a lath nailed across the bottom; and the workman standing upon it in wooden shoes mixes the sand with water, and gently moves it against the current with a wooden hoe or colrake. The precious metal thus arranges itself chiefly near the head-board of the frame, and when a certain amount is deposited he rakes it with his hoe just strongly enough to draw down the waste particles over the lath to the lower division, and yet not strongly enough to disturb the richer deposit. This delicate operation must be continued till he has got rid of all the coarse fragments, after which he diminishes the flow of water, and by light brushing raises again all the slime which may still remain, and as much as possible of the magnetic iron ore, and takes up the remainder, the "black schlich," as the product of his manipulation. That which has settled in the lower half of the frame is then brought upwards, and passed once, twice, or thrice, through the same operations. The proceeds of this "fine-washing," as it is termed, for which the most skilful workmen are required, may be then dried, and freed from a further quantity of magnetic iron by the use of a piece of load-stone, or a magnet.

The "gold-trough" used in Hungary for the analogous purpose of cleaning the powder or meal obtained from the gold-cloth tables above referred to is about 8 feet long by 1½ broad, with an inclination of from 2 to 4 inches per foot: it is used in a very similar manner to the above, a little broom of heather or birch being employed instead of the hoe for raising the particles which are to be separated from the gold. In Transylvania its dimensions are

much larger; and it is fitted with two traps in its floor, into which the different qualities of "schlich" are swept at different stages of the process. The resulting products are sometimes further concentrated in the bowl to a state fit for melting, or are subjected to amalgamation.

Particulars of a much more detailed nature, however wearisome to a general auditory, would be indispensable to those who wish critically to take in hand these subjects; and I have to regret that the preceding descriptions have occupied so much of our time, that I can do no more than allude, in passing, to the last-mentioned process of amalgamation, so important where we have to deal with gold obtained from actual mining. Such gold, generally in minute particles, is mingled with various other minerals and rocks,—as pyrites, zinc-blende, quartz, &c.; and can only be extracted after the whole has been reduced by stamping to a very small size. In Hungary, and also in the Salzburg Alps, the amalgamation is combined with the stamps in a very simple and efficient manner. Close below the stamps "cofer," or trough, the water, carrying with it the pounded particles, is led into shallow bowls of cast-iron, in the bottom of which is a layer of quicksilver. In each of these bowls a "runner," supported on a central spindle, revolves by machinery, and stirring the mixture which has flowed in brings it in contact with the quicksilver, and then allows it to pass out by a spout. After passing through two of these bowls, the sand or slime is led over a series of cloth tables, where some little gold and quicksilver, along with auriferous

pyrites, &c., is caught up, whilst the rest passes away to be further treated by buddles and frames.

Very similar apparatus has now been at work for many years in some parts of Brazil; and to give you an idea of what may be done with poor ores, when system and skill are brought to bear, I will give you in round numbers the average produce obtained from the stamped ores at Schemnitz, in Hungary, in 1842, which you will recollect had to be broken from the solid lodes at depths extending to 200 fathoms. The total quantity stamped was above 40,000 tons, and the average of the useful metals extracted from 50 tons was,—gold, 3 oz.; auriferous silver, derived from the separating processes, buddling, &c., $3\frac{3}{4}$ lbs.; lead, similarly obtained, $8\frac{1}{3}$ cwt.: the ratio of gold to the other materials being here as 1 part to half a million.

Or take the case of a particular mine called Siglisberg, not producing lead with the stamp ores, the ratio of gold was as 1 part in 760,000; of auriferous silver, 1 in 24,000.

To compare with this economical extraction of minute quantities the manipulation of the Siberian gold washings, we find that a common average of the sands worked to profit is $\frac{1}{2}$ oz. in 100 cwt.; or 1 part in 320,000.

In conclusion, it may be permitted me to address to you a few remarks on a point of the highest moment to those among you who are about to seek your fortune in a distant portion of the globe, to us who remain behind, and to the civilised world at large.

The pursuit of gold, actual, tangible, metallic gold,

has been generally, and not without reason, stigmatised by all classes of writers,—by poets, philosophers, historians, and moralists, as productive of disastrous results to the seekers themselves, and to the community in general. I have myself been a wanderer in regions, where the sudden discovery and publication of gold stream-works has for a time paralysed other branches of industry, upset the ordinary relations of employment, and locally unhinged the framework of society. This has been exhibited on a small scale in Transylvania, before the horrors of the late civil wars devastated her fair valleys; and we have more lately seen how some of the same results have occasionally occurred in California. But the Anglo-Saxon element, which has in the last-mentioned country so generally succeeded in repressing these too natural disorders, is destined, we may hope, to play a noble part at the Antipodes, by proving to the world how much a spirit of self-reliance combined with the love of order may effect, in withstanding the incitations of unjust cupidity.

You, who have here experienced the blessings of reasonable freedom, and of the upright administration of law, must stand forward for the preservation of similar advantages in your adopted country. There may very possibly be some among you who think that, pressed by a heavy taxation, they have, under our British *régime*, too much to pay for this security of person and property. But as one who has painfully toiled, heavy laden with weapons, through some of those Eastern lands, where law is a dead letter, and where every man must protect himself as he best may, let me impress on you the conviction,

derived from facts and from conversation, that to the industrious of such countries no sacrifice would appear to be too great for the purchase of the blessings to which I have alluded; and that many an honest, persevering man would give up, not one-tenth, but nine-tenths of what he possesses, to secure himself impartial justice, and the preservation of his life and earnings against the attacks of the unprincipled.

A motley crowd must shortly be assembled in those gold-fields of Australia, hitherto almost a wilderness, and among them will, doubtless, be found some unruly spirits, whom ignorance and avarice together may incite to turbulence and evil; but we may reckon confidently on the superior training and inbred love of good which will characterise the majority of those who are now proceeding from among us, to support the endeavours of the authorities in maintaining peace and order under circumstances of great difficulty, and to spread around them that feeling for enlightenment and rational progress so essential to the lasting prosperity of their newly-born community.

With every wish for the individual success of those who intend to seek for wealth by honourable toil, we may fearlessly expect that their united efforts, so long as they are not forgetful of themselves and the well-tried institutions which they leave behind them, will at the same time contribute to the honour and advantage of the colony, the mother-country, and of civilisation.

LECTURE V.

THE METALLURGICAL TREATMENT AND ASSAYING OF GOLD ORES.

BY

JOHN PERCY, M.D. F.R.S.

LECTURER ON METALLURGY AT THE GOVERNMENT SCHOOL OF MINES AND SCIENCE APPLIED TO THE ARTS.

JOHN PERCY, M.D., F.R.S.,

ON

THE METALLURGICAL TREATMENT AND ASSAYING OF GOLD ORES.

The present lecture is essentially and entirely practical. It was not originally prepared with the slightest view to publication. Without copious illustration by specimens and experiments, it is very difficult to communicate information of value to an audience such as the writer had the honour to address at the Museum. For certain reasons, however, it was considered expedient to publish this short course of lectures under the sanction of the respective lecturers, especially as the publication of them was proposed by several other persons without the co-operation of the lecturers. And it is well known that the lecturer is frequently made to say the opposite of what he did say, if the reporter be not well acquainted with the subject. To guard against such accidental misrepresentation was certainly the chief reason which induced the authors of this volume to commit their productions to the press.

The author has endeavoured to expound the principles concerned in the metallurgical treatment and assaying of

gold ores, and to give as much detail as he conceives will be specially useful to those who may wish, in Australia, to educate themselves in these matters. Great practice and close observation will alone produce skill in the very responsible and important department of assaying, and the reader is cautioned to be at first extremely distrustful of his results, until he has verified them by repeated trials. Assays must be correct, or they are worse than useless, as erroneous results must necessarily tend to heavy pecuniary loss, either to the buyer or seller.

Composition of Gold Ores.—Gold almost always occurs in the metallic or native state, generally in small particles, but occasionally in pieces of considerable weight. It is never pure, being almost invariably alloyed with silver, and containing frequently small proportions of copper and iron. The accompanying table presents the composition of native gold from various parts of the world. And it will be observed that while in some specimens the proportion of silver is very small, in others it forms a considerable percentage.

The proportion of silver varies not only in specimens of native gold obtained from different regions, but even in specimens from the same auriferous district. In Hungary gold is met with in combination with tellurium and other elements; and in Brazil an alloy of gold and palladium has been discovered. Gold frequently exists in certain kinds of iron pyrites, which occur abundantly in this country, as well as in other parts of the globe. [Specimens of gold were placed before the audience extracted from

iron pyrites from Alston Moor, in Cumberland, from Wicklow, in Ireland, and from California.]

Composition of Gold Ores.

LOCALITY.	AUTHORITY.	GOLD.	SILVER.	COPPER.	IRON.
		Siberia and Ural.			
Schabrowski	Rose	98·96	0·16	0·35	—
Boruschka..........	Do.	94·41	5·23	0·36	
Katharinenburg	Do.	92·80	7·02	0·06	0·08
Gozuschka	Do.	83·85	16·15	—	—
Ural	Awdejew ..	70·86	28·30	0·84	
		Africa.			
Anamaboc	T. H. Henry	98·06	1·39	0·15	
Do.	Do.	88·25	11·17	0·10	0·36
		America.			
North of Brazil......	Rivot	91·0	8·7	0·3	Palladium.
Gongo Soco.........	T. H. Henry	83·36	6·44	0·50	3·58
Ojas Anchas	Boussingault	84·5	15·5	—	—
Santa Rosa de Osos..	Do.	82·4	15·5	—	—
Marmato	Do.	73·45	26·48	—	—
Titiribi, Columbia ..	Rose	76·41	23·12	0·03	—
California	T. H. Henry	90·12	9·01	0·87	Iron.
Do.	Do.	86·57	12·33	0·29	0·24
Canada	Do.	90·38	9·53	—	—
		Australia.			
Bathurst	T. H. Henry	95·68	3·92	—	0·16
		Europe.			
Transylvania........	Rose	60·49	38·74	0·77	
Wicklow	Mallet	92·32	6·17	—	0·78

It appears doubtful whether in every instance the gold exists in pyrites in minute metallic particles, or whether, in some instances at least, it may not be present in combination with sulphur. Gold is thus widely diffused over the surface of the earth, though rarely in sufficient proportion to make its extraction profitable.

The public cannot be too urgently cautioned against the error of supposing that where gold is found, there is necessarily an opening for the investment of capital. Of all metallurgical processes, the extraction of gold is generally the most costly. It is true that occasionally large pieces have been discovered, but they are *rare* exceptions. To extract sixteen shillings' worth of gold from the pyrites of the vein called the "back-bone," near Alston in Cumberland, on the authority of my friend, Mr. Pattinson, of Newcastle-on-Tyne, it would be requisite to expend a sovereign. No sooner, however, are the marvellous discoveries of California and Australia made known,—and marvellous, indeed, they are,—than we are informed of the existence of a similar El Dorado in this country; but the evidence which has hitherto been advanced in support of this statement is, in my judgment, insufficient.

I would take the present opportunity of insisting strongly upon the necessity of exercising the greatest caution in the sampling of gold ores. Careless sampling can only mislead. Assays of individual specimens may be accurate; but they are worse than useless if the assayer has not operated upon an *average* sample of the ore. I would advise the capitalist, to whom prospectuses of gold-mining schemes may be submitted, not to be allured with

glittering specimens of gold-ore, with assays yielding a high produce, and with the glowing statements of sanguine promoters, or enthusiastic adventurers, without having ascertained on good evidence that the samples which are presented to his notice are really *average samples* of the ore, and that something like a continuous supply may reasonably be expected. If such specimens do not represent an average, they become what the Cornish miner calls "Slocking-stones," which are at all times enticing and dangerous to the inexperienced and unwary, and never more so than in the case of auriferous ores. I consider that in uttering this advice, which I believe to be specially needed at the present time, I am simply discharging a duty which, in virtue of my appointment, I owe to the public.

Melting of the Gold-dust.—The first metallurgical operation to be considered is the melting of the "gold-dust," as it is received from the "gold-washer." Good black-lead crucibles* are heated in a common melting furnace (such as is employed by the brass-founder), and the "gold-dust" is then carefully introduced, having been previously mixed with a little dried borax. When the metal is melted, a slag will be found swimming on the surface, which must be thickened by the addition of bone-ash, and then skimmed off. The metal is cast into bars by being poured into open iron ingot-moulds of the usual dimensions. The mould should be previously warmed and

* Black-lead crucibles of this kind are made by Mr. Ruel, of 176 High Holborn.

oiled by wiping the surface, which comes in contact with the melted metal, with a piece of tow dipped in sweet oil. Some refiners in melting the "gold-dust" add to the metal when melted a small quantity of "corrosive sublimate," and stir at the same time. Effervescence, the effect of the volatilisation of the sublimate, takes place. This is an old practice, and by some metallurgists is regarded as useless. It seems, however, probable that by thus introducing a volatile body into the metal, and so causing agitation throughout the mass, any small particles of extraneous matter, which might be detached from the surface of the crucible, and become diffused through the metal in casting, may be brought to the surface and removed with the slag. Before using the "black-lead" crucibles it is customary, with some persons, to coat the external surface with fire-clay by dipping them in a cream of fire-clay and water. The crucibles which have been used should be kept, as they will retain a portion of gold, which must be extracted in a smelting operation. The dimensions of the crucibles may vary according to circumstances.

Smelting of Gold Ores.—The term "smelting" is technically applied to a process, or series of processes, by which a metal is extracted by the agency of fire from the substances with which it may be combined or mixed in nature. In the consideration of the smelting of gold ore, the metallurgist should be acquainted, not only with the composition of the native alloy of gold, but with the various foreign matters with which it may be associated. The most important of these are as follow:—

1. Silica, of which quartz or common sand almost entirely consists.

2. Other earthy matters, as clay.

3. Oxides of iron, especially magnetic oxide.

4. Iron pyrites.

5. Galena.

6. Blende.

7. Complicated ores of gold, like many of the South American, which contain iron and copper pyrites, galena and blende, arsenic and antimony, and various earthy matters.

Smelting of Gold associated with Silica.—In California, especially, large veins of quartz have been found containing gold diffused through the mass in variable proportion; and much has, of late, been said and written respecting the smelting of what has been called "gold quartz,"—in other words, of the extraction of the metal from the quartz in the furnace. I do not pretend to give any opinion at present respecting the precise conditions in which it may be desirable to smelt the quartz in preference to stamping and washing in the manner described by Mr. Smyth. Taking it for granted that it is expedient to adopt the smelting process, I shall simply describe what I conceive should be the principles to guide the smelter. But the reader must be cautioned, that however simple the operation of smelting may appear to him, yet that, to carry on successfully even the simplest process of smelting, considerable experience is *absolutely* necessary. Only they who are practically acquainted with metallurgical operations of this kind can

adequately appreciate the necessity of this caution. In the management of a furnace there are a hundred points, a knowledge of which can only be acquired by practice, and which it would be impossible to communicate by description.

When a piece of quartz containing gold diffused through its mass is exposed to a degree of heat even far exceeding that of melted gold, no separation of the metal takes place, owing to the infusibility of the quartz. The metal, indeed, is melted and liquid, but it is obvious that as it is present only in very small proportion in comparison of the infusible quartz, it must necessarily remain diffused as at first. But if a substance be added which, at a high temperature, shall combine with the quartz, and produce a fusible compound, then it is equally obvious that the gold will, by virtue of its high specific gravity, rapidly fall to the bottom of the vessel in which the experiment is performed. Now, carbonate of soda is a substance which would act in this manner upon quartz. It would render it fusible at a high temperature, or cause it to "flow;" in other words, it would "flux" the quartz, and would, consequently, be designated by the metallurgist as a "flux." The product of this combination is a "slag," which, in this particular instance, is a true glass, very similar in appearance and other respects to common crown or window-glass. But as the gold would occupy only a very small volume compared with the quartz, it would be difficult to collect it without very sensible loss in a crucible, still more so in a furnace, whether reverberatory or blast. It is, therefore, desirable

to add a something which shall serve the purpose of diluting and collecting the gold, and from which it may afterwards be readily extracted. Of all substances lead is generally the best for this purpose, and has accordingly been uniformly employed in all smelting operations with gold ore hitherto carried on. As in the amalgamation mills mercury is employed to seize hold of and amalgamate with the minute particles of gold, which might otherwise escape, so lead is used with the same object in the smelting of matters containing gold. The part which mercury plays at the ordinary temperature is that which lead plays at a high temperature.

In order to facilitate the combination of the quartz with the "flux" (which for the present we suppose to be carbonate of soda, although the metallurgist would, on the score of expense, be entirely precluded from the use of that substance on the large scale), it must be reduced to a comparatively fine state of division by crushing in one way or other, otherwise a very considerable time would be required to effect the perfect combination, and the combination must be perfect to ensure the satisfactory separation of the gold; for, as Mr. Smyth remarked, in reference to the stamping or crushing of gold ores, if particles only as large as a pea be left undissolved by the action of the flux, those particles may contain gold, and so a considerable loss of the precious metal may result. In the ore-furnace of the copper-works at Swansea, it is true that comparatively large pieces of quartz may be seen diffused through the slag, but this must not furnish ground for supposing that a similar slag might be tolerated by the gold-smelter.

Although carbonate of soda could not, for the reason stated above, be used by the smelter, yet there are various substances which will readily "flux" quartz, and may be had at a sufficiently cheap rate. Lime, in certain proportions, alone will at a high temperature combine with quartz, and produce a fusible slag, but the fusibility would be much aided by the addition of oxide of iron. Hence a mixture of lime and oxide of iron in suitable proportions may be conveniently employed by the smelter. When practicable, it would be desirable to obtain the oxide of iron by *roasting*,—that is, burning, with the *free* access of air,—an auriferous pyrites, such as the Californian, for then the proportion of gold would be increased by that contained in the pyrites, from which, possibly, it could not otherwise be profitably extracted. Lime and clay in certain proportions produce a fusible slag with quartz. The common and well-melted cinder of our iron furnaces is composed practically of those three constituents. Quartz and fluor spar will also melt when mixed in certain proportions and exposed to a high degree of heat. Oxide of iron alone will suffice. The common and very fusible slag of the puddling-furnace is chiefly composed of oxide of iron and silica. Various experiments and facts on this important practical subject will be given at the end of the lecture for the purpose of reference, but the metallurgist will be readily able by a few experiments to obtain the knowledge he may desire, if he will remember the leading facts just mentioned.

It must not be supposed that the unpractised metallurgist will experience no difficulty in conducting such operations on the large scale. The corrosive action of

lime, and especially of oxide of iron, on the material, such as fire-brick, of which furnaces are constructed, is very great, and sometimes extremely perplexing. One great point should be to keep the bed of the furnace (if reverberatory) protected as effectually as possible by a stratum of melted metal. If oxide of iron be employed, the reverberatory-furnace is to be preferred, because in the blast-furnace a considerable portion of the oxide of iron would certainly be reduced, and a corresponding quantity of metallic iron liberated long before the mixture attained the degree of heat requisite for the combination of the silica with the oxide. I much regret that in the very limited space of a single lecture it is utterly impossible to enter upon various important practical details concerning the construction of furnaces, which, to be properly treated, would require a volume of text illustrated with numerous drawings.

The lead may be added to the mixture of ore and flux either in the metallic state or in a state of combination, from which the metal may be set free. Common litharge, mixed with charcoal or coal-slack to the extent of about five per cent, may be employed; or galena, mixed with a sufficient proportion of scrap-iron to deprive it of its sulphur and liberate the metallic lead. A mixture of galena and litharge in certain proportions, or galena roasted to a certain degree mixed with iron, or the lead-slag which comes from the "ore-hearth," or the reverberatory-furnace, may be similarly used when ground to powder under the edge-roll and mixed with charcoal or other carbonaceous matter. This

lead-slag is generally the most convenient and least expensive material for the purpose. It contains a considerable percentage of lead, which, when under the conditions mentioned, is evolved, and, percolating through the mass as it subsides by virtue of its high specific gravity to the bottom of the furnace, carries along with it any particles of the precious metal it may meet with in its course. Lead-slag has long been extensively used, both at Sheffield and Birmingham, in the refining of "sweep," or the dust of jewellers' and silversmiths' shops. The "sweep" is mixed with the ground slag and coal-slack, and smelted in the reverberatory-furnace. Some scrap-iron is also occasionally added for the special purpose of combining with any sulphur which may be present in the slag. It is especially important to make this addition, to prevent loss of silver in the slag. Formerly thousands of tons of lead-slag, rich in lead, were thrown away, but have of late been greedily sought after, and worked to considerable profit for the lead.

Some years ago Anossow, a Russian, proposed to smelt the gold sand of the Ural with iron, alleging that a very much larger quantity of gold could be so obtained than by the most skilfully conducted process of washing.* His statements, indeed, respecting the advantage of the use of iron for this purpose are obviously so exaggerated as to render them unworthy of confidence. Experiments are reported to have been made on the large scale, and to have perfectly succeeded; but the best proof of the want of

* Anleitung zum Gold, Platin, und Diamenten-Waschen. Von Dr Carl Zerrener. 1851. P. 50.

success is the fact that Anossow's process has never been adopted, as it unquestionably would have been had only a fraction of what he had stated in regard to it been correct. Cast-iron was employed simply as a vehicle to collect the gold instead of lead. The iron was dissolved by sulphuric acid, and the gold remained in the insoluble residue. Some experiments have been made at the Museum on this subject, which indicate that if it were advantageous on the score of economy cast-iron might be so applied. The metal may either be added directly, or in the state of a common oxide of iron under conditions favourable to the reduction of a portion. When cast-iron is melted with gold an alloy seems to take place, from which the greater part, if not the whole, of the gold may be extracted by melting the cast-iron in contact with lead, which abstracts the gold.

Recently many notices have appeared in the newspapers respecting another smelting process for quartz containing gold.* It is secured by patent, and, as I have received information concerning it from several persons without any restriction as to secrecy having been imposed upon me, I consider myself at liberty to make some observations upon it. The quartz is crushed to a small size, and "fluxed" with a mixture of lime and oxide of iron. Plates of wrought-iron are from time to time introduced into the furnace and withdrawn when the surface is found to be coated with a film of gold. They are

* It may now be stated that Mr. Longmaid is the inventor referred to, and that the author having submitted the following description to that gentleman, no objection was offered on his part to the publication.

then plunged into melted lead, which dissolves off the precious metal, and afterwards again put into the furnace. This process is constantly repeated, and the gold, it is asserted, is thus obtained both more economically and in greater proportion than it could be by the process of stamping, washing, and amalgamation. The slag is stated to be free from gold, as I think it must necessarily be under the circumstances. The use of wrought-iron in this process I believe to be quite original. Experience will soon decide whether the invention is really so practically valuable as is maintained. There is evidently a constant loss of wrought-iron, and a considerable expenditure of manual labour, and lead is the ultimate solvent. It requires, in the first place, to be shown, in proof of the efficacy of the process, not whether the slag is free from gold, as it must be under the circumstances, but whether the whole of the gold is directly extracted; and, in the second place, whether this method of smelting is cheaper than that in which lead is directly employed. There is also another point deserving of special attention: it is, that as the gold certainly in very great measure exists in the quartz in the metallic state, it must necessarily, in part at least, penetrate through the melted mass, and come in contact with the bed of the furnace, escaping the plates of iron. But the bed of a furnace in which the smelting is effected must consist of some very refractory materials other than iron itself; and so far as I am aware there are no such materials which are impermeable to melted metal. It is true that the bed of the furnace may rest upon plates of iron, as is the case in

many reverberatory-furnaces, and so ultimate loss of gold may be prevented. It is, however, far from desirable that any quantity of a precious metal should, so to speak, be locked up even for a short time in the bed of a furnace. Some idea of the extent of this permeation of the bed of a reverberatory-furnace may be formed when it is stated that even in the modern construction of the reverberatory-furnaces in use at the copper-smelting works at Swansea, some tons of metal may be so infiltrated. I have seen in various metallurgical works the beds of reverberatory-furnaces constructed with the greatest care, to diminish as much as practicable the temporary loss of metal from permeation, but when the beds have been removed in the process of repair a comparatively large quantity of metal has been recovered from them. Probably the inventor has devised some satisfactory means to prevent this temporary loss; for, otherwise, the infiltration even *of a few pounds* of gold would, from loss of interest, be virtually an important item in the cost of the process.

Another vehicle which is applied to collect the gold in the process of smelting is *iron pyrites*. When common iron pyrites is heated to a certain temperature without access of air, it loses half of its sulphur, and the product is a fusible sulphide of iron, such as is produced by bringing a roll of sulphur in contact with a bar of iron heated white hot in a smith's forge. Let there be given, for the sake of example, an ore consisting of auriferous iron pyrites and quartz; when such an ore is mixed with the appropriate "flux" for the quartz, as already described, and exposed to the requisite heat, a slag will be obtained, and below the

slag will be found a stratum of sulphide of iron containing the gold. This stratum is called a "matte," a technical expression adopted from the French. If, then, this "matte" be roasted, that is *oxidised,* by heating it with the free access of air, and the product be mixed with a fresh quantity of crude auriferous pyrites, and smelted again, a second "matte" will be obtained which will contain the gold from the two portions of ore employed. The gold is thus capable of being concentrated in sulphide of iron. The process may be again repeated until the precious metal has been sufficiently concentrated to admit of its profitable extraction. The final "matte" is then melted in contact with lead, which deprives it of its gold, the impoverished sulphide of iron floating on the melted lead. The roasting of the pyrites may be effected in large heaps in the open air, at the bottom of which is placed brushwood or other convenient fuel to ignite the mass, which, when once ignited, continues to burn. In this process the silica and oxide of iron must be so adjusted as to act as mutual "fluxes," and there must always be present sufficient sulphide of iron to form a distinct stratum. This process has long been practised in Hungary.

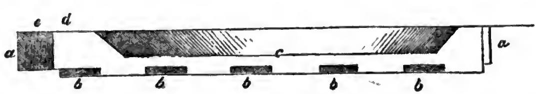
Extraction of the Gold from Lead.—This is invariably effected by what is termed cupellation, a process in use from the most remote antiquity. When lead is heated to a temperature above its melting point, it rapidly combines with the oxygen of the air, or burns, the product being yellow oxide of lead; and when the temperature is raised to about bright redness this oxide melts, and is then known as litharge. But when gold is heated with access of air,

even at the highest temperature of our furnaces, it neither volatilises nor combines with oxygen. Melted oxide of lead very readily permeates various substances; such, for instance, as the refractory material of various crucibles. One of the substances most readily infiltrated by it is bone-earth, burnt and reduced to fine powder, and then compressed into a solid state in a mould. Into a small, short hollow cylinder of iron beat some pounded and sifted bone-ash; then place upon the surface of the bone-ash, which should be made concave, a piece of lead of the size of a small shot. Direct upon it the outer point of a blowpipe flame. The lead will rapidly oxidise, and the surface of the small melted globule of lead will be seen to be covered with an iridescent film in rapid motion. This film is melted oxide of lead, which is no sooner produced than it is immediately absorbed by the bone-ash with which it comes in contact, just as a drop of water is absorbed by a piece of blotting-paper. But no sooner is this film removed than it is replaced by another, a fresh surface of metallic lead being exposed to oxidation. There is thus a continuous production and absorption of oxide of lead, and at length every trace of metal disappears. When cold, the bone-ash will have a fine yellow colour due to its impregnation with oxide of lead; and during the course of the process of oxidation vapour will be observed proceeding from the globule of metal, which is the vapour of metallic lead in the act of conversion into oxide. If, instead of thus treating a shot of pure lead, an alloy of gold and lead be similarly treated, then the lead will disappear as before, and the gold will remain on the surface of the bone-ash as a shining globule. If, however, a small shot of copper be

treated in the same way upon the bone-ash, it will melt and rapidly oxidise; but the black oxide of copper, owing to its infusibility at this temperature, will not pass into the bone-ash, but will remain on the surface. If, on the other hand, a certain proportion of lead be added to the copper, and the operation be then conducted as before, the oxide of lead will combine with and dissolve the oxide of copper, and both will completely pass into the bone-ash, which, on cooling, will be found to have acquired a blackish colour. Pure copper requires not less than sixteen or seventeen times its weight to lead to be thus absorbed. Hence it follows, that not only may lead be readily separated from gold by this process of cupellation, but that gold may be deprived of copper by cupelling it with lead; and what is here said of gold is also true of silver. On the large scale it would not be desirable to cupel an alloy of lead and gold alone, but always to add a certain proportion of silver both for the purpose of diluting the gold, and so diminishing the chance of loss, and to prepare it for the subsequent operation of "parting," or the separation of the silver. Native gold, it has been remarked, is nearly always alloyed with a certain proportion of silver, which must be dissolved out either by nitric or sulphuric acid. And, in order to this, the gold must be alloyed with from two to three times its weight of silver. Hence it is desirable to insure the presence of at least this ratio between the silver and gold in the lead.

Cupellation, or refining, on the large scale.—The English method is as follows: A piece of bar-iron, about half an inch thick and four inches deep, is bent into the form of an oval hoop, and the ends of the bar are welded together.

On the lower side are attached a series of parallel flat bars of iron in the direction of the short diameter of the oval. The dimensions of the apparatus may vary considerably, according to circumstances. The long diameter generally does not exceed four feet, and the short two feet six inches. Pounded and sifted bone-ash is mixed with about one-tenth by measure of fern-ashes, or one-fortieth by weight of American pearl-ashes, and moistened sufficiently to become coherent by pressure.* The hoop above-mentioned is then placed with the cross-bars downwards upon a solid floor, and the bone-ash beaten firmly into it with a mallet or rammer until it is entirely filled, or the bone-ash is level with the upper edge of the hoop. This done, the surface is carefully scooped out, so as to form a shallow concavity of about two inches and three-quarters in depth, and leave a wall of bone-ash all round of about two inches in thickness, except at one end, where the bone-ash is cut out so as to leave an open space between it and the iron; but the thickness of bone-ash at this end, which is called the breast, is about five inches. The apparatus thus prepared is technically called a "test." It is allowed to dry,



Drawing in section and plan of a test from Karsten's Metallurgy.
a a Iron hoop. *b b* Transverse bars. *c* Cavity.
d Breast. *e* Space between the breast and the iron.

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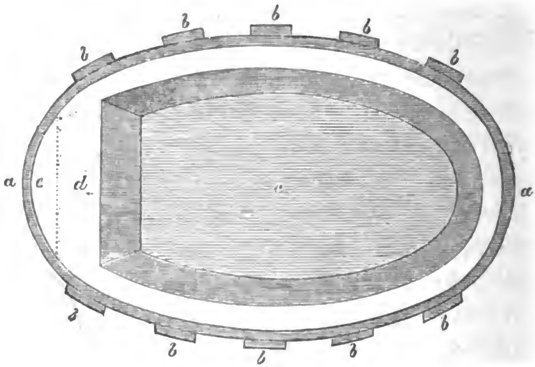
* On the Smelting of Lead Ore, by H. L. Pattinson, F.R.S.; "Transactions of the Natural-History Society of Northumberland," &c., vol. ii. part 1, p. 169. The best description in the English language.



when it is placed in a furnace constructed in all respects like an ordinary reverberatory-furnace, except that a space is left open in the bed of the furnace to receive the test, and that the long axis of the arch is very short. The test, in fact, forms the bed of the furnace, in which it is adjusted with the long diameter transversely. It is supported in its place by iron bars placed underneath between the two walls of the furnace. At the end opposite to the breast, and through a space left in the side of the furnace, the nozzle of a pair of large double bellows, or a fan-blast, is introduced. The furnace having been heated to a sufficient degree, which can only be known by experience, lead containing the silver and gold is placed upon the test, so as to fill the hollow cavity when melted. Oxidation proceeds rapidly, the blast is directed on the test, and the litharge at first sinks into the test, which it soon saturates, and then begins to flow through a channel, which must be cut in the surface of the breast, or wall of bone-ash, at the opposite end of the test, so

that it may run over the end, and not come in contact with the iron. It was for this reason that the bone-ash was directed to be entirely removed at this end, as the melted oxide of lead would exert a powerfully corrosive action on the iron. In proportion as the litharge is formed, lead is gradually supplied to the test, which is easily done by lading it into a channel from an iron pot outside the furnace kept filled with melted lead. After the lapse of a certain time, the channel through which the litharge first flows becomes much corroded, and must then be stopped. A fresh channel must be made by the side of the former across this end wall or breast of the test, and the operation continued as at first; and again it will be necessary, in the course of the process, to construct a third similar channel. Iron pots on wheels are placed below the furnace to receive the stream of melted litharge. In this manner several tons of lead may be refined on the same test. Towards the conclusion of the operation some striking appearances are presented. As soon as the last portions of lead are removed as oxide, the silver suddenly assumes a bright and resplendent surface. Shortly afterwards, as it cools, its surface is suddenly thrown into agitation; cones, or little craters, sometimes several inches in height, are thrown up, from which oxygen gas escapes with violence, projecting particles of silver with considerable force. This phenomenon is termed "spitting," or "vegetation." It has been shown that "fine," or pure metallic silver, when melted, has the property of dissolving, so to speak, much more than its own volume of oxygen, which escapes with violence at the moment of solidifica-

tion, giving rise to the eruption from the surface described. Generally it is usual to employ one test with a flat bottom of bone-ash to concentrate the silver in the lead, and a second with a concave bottom to conclude the operation of cupelling or refining. In the Museum is a beautiful cast of a cake of silver, of the weight of 3000 ounces, which was prepared on a test for the Great Exhibition of last year by Mr. Pattinson. It is scarcely necessary to remark, that in properly conducting the process of cupellation, simple as it may seem, much experience is required. After the operation, the test, with its cake of silver, is withdrawn from the furnace, the silver removed and cleaned, and the bone-ash saturated with litharge knocked out and preserved for subsequent treatment, as it contains a considerable quantity of lead in the state of litharge, and some silver also.

On the Continent the process of refining is conducted differently. The test is not movable, but is, in fact, the bed of the furnace itself, which is shaped into a circular cavity, sloping from the sides to the centre. This bed consists of a kind of marl, which is firmly beaten in and allowed to dry. The roof of the furnace, on the other hand, is movable: it consists of a flat dome of bricks, built in a strong, circular hoop of bar-iron, which is attached to a crane by three or more chains. The furnace is provided with a blast, which enters by one or more apertures at one side. The lead which is refined in these furnaces is generally very impure. The greater part of the impurities rise to the top after the furnace has been in operation for some time, and are skimmed off and placed by themselves for further treatment. The

purer litharge then follows. The operation is continued till the lead is removed and the silver left fine. The furnaces are large, some tons of metal being introduced at once, and worked off continuously without further addition until the conclusion of the process.

Assaying of Gold Ores.—By assaying is meant the determination, by a ready method, of the proportion of metal existing in any given ore. Assaying is said to be either "wet" or "dry," according as the agency of liquid solvents or of "fluxes" and fire, is employed. For practical purposes in the determination of gold, the latter process is always adopted, while in the subsequent separation of the silver the former is resorted to. Formerly the silver was separated by a "dry" method. The processes of "dry" assaying may be regarded as smelting processes in miniature. It will not, therefore, be necessary to explain the principles upon which this important department of the subject is founded, as the principles already enunciated, in reference to the smelting of gold ores, apply equally to the assaying of these ores.

Quartz containing Gold.—Reduce the quartz to fine powder by triturating in an iron mortar. Trituration is much facilitated by heating the quartz to redness and plunging it in cold water. Above everything be particular in obtaining an honest and fair average sample. This is a matter of paramount importance, and of no small difficulty in many cases. But let there be honesty of intention, and that difficulty will generally be surmounted. The sampling generally devolves upon the miner, but the assayer and metallurgist should also understand the business.

Assayers of great experience and high integrity may occasionally commit unintentional mistakes. Thus, a few years ago, two small pigs of lead from South America, very rich in silver, were offered for sale. They were assayed by assayers of very high standing. Portions had been taken from the top and bottom of each pig, with a view to obtain a fair average. I had occasion to attempt to verify the report of the assayers. Portions were taken from the same parts of each pig as in the first instance; but the results did not agree with the report, nor did my assays agree with each other on taking fresh portions. It was, therefore, certain that the composition was not uniform, and that the portions taken for the purpose of assaying in neither case represented an average. The pigs were accordingly sent again to the same assayers. Each pig was melted separately, and while melted a sample was taken. A second report was given, which differed from the former to the extent of 1000 ounces and upwards to the ton! In the sampling of gold ores most especial care should be taken, as the precious metal exists irregularly diffused through the mass in particles of very different size, and as minute errors in sampling will necessarily be greatly multiplied, when the quantity of gold per ton is calculated from the assaying of, it may be, 500 or 1000 grains of ore.

Method by Fusion.—Of the sample make at least two assays, in order to test the correctness of the result. Weigh 500 or 1000 grains, and mix intimately with about the same weight of dry carbonate of soda, and half the weight of red-lead, with five per cent of char-

coal, or, instead, use granulated lead. The precise quantities are not very important. Let there be plenty of carbonate of soda, of which it is better to take too much than too little. Then introduce the mixture by means of the copper scoop into a Cornish or black-lead crucible, previously heated to redness. Fix it solidly in the assay furnace by surrounding it with fuel. Heat carefully and watch the operation. Effervescence will take place, owing to the displacement of the carbonic acid from the carbonate of soda by the silica, and from the combination of the carbon with the oxygen of the red-lead. Continue to heat, raising the temperature towards the last to bright redness, until no further effervescence occurs and the slag appears clear and well melted. Then take the crucible immediately from the furnace, and as dexterously and as rapidly as possible pour as much of the slag as you can into one of the two hemispherical cavities of a suitable cast-iron ingot-mould, and the lead with adhering slag into the other. It is well previously to oil the mould, as before mentioned. Examine the slag to see if any shots of lead are contained in it. If there are, they must be carefully separated by trituration and washing with water. Take out the button of lead and strike it carefully on the side, on a bright anvil, with a hammer, and so detach adherent slag. The gold will be found in the lead, which is to be cupelled in the way to be subsequently described. In the absence of carbonate of soda, lime and clay, or lime and oxide of iron, might be employed. It is worthy of remark, that the Californian gold-bearing quartz contains a very sensible amount of magnetic oxide of iron. This

may be readily proved by carefully washing the triturated quartz in a bowl, drying the blackish residue, and extracting the oxide of iron with a magnet. At the Museum, the presence of this oxide, which is not conspicuous in the ore, has always been found in considerable quantity by this method. I have examined a very rich sample of auriferous magnetic oxide of iron, which found its way from California to Birmingham more than two years ago.

To determine the presence of gold in auriferous pyrites proceed as follows:—Reduce to fine powder and roast on a shallow dish of refractory clay, heated to low redness in a large muffle, until the odour of burning sulphur has ceased to be evolved. The temperature must be very gradually raised to bright redness as the sulphur burns away. Oxide of iron is the product. Of this take 1000 grains or more and mix with 500 of dry carbonate of soda, 300 to 500 of red lead mixed with charcoal, or the same quantity of granulated metallic lead, and about 500 of dried borax. Heat, and, in other respects, proceed as before.

Instead of pouring out the contents of the crucible into the ingot-mould, the whole may be left to cool, and when quite cold the crucible may be broken. The button of lead at the bottom must be struck edgewise on the anvil to detach adherent particles of crucible and slag. The fuel should be either charcoal, coke, or anthracite. Each has its peculiarities, which will be soon understood by a little experience. At the Museum, anthracite, as fr from ash as possible, has been employed with advantage, its use having been suggested by my friend Mr. Henry. Anthracite appears to be characterised by the following

qualities,—its power of producing an intense heat in a short time over a space confined to a few inches above the bars.

The assayer must, in many cases, make a few preliminary trials respecting the proper mixture of "fluxes" when he is called upon to assay an ore which is manifestly different from what he has been accustomed to operate upon. He should remember that borax is especially the "flux" for metallic oxides, and carbonate of soda for silica. Frequently a mixture of the two is requisite.

In some cases in which metallic sulphides may be present in considerable quantity, and the assayer wishes to avoid the trouble of roasting, the cautious and gradual addition of *nitre* may be made, or red-lead in excess *without carbon*, a sufficient quantity of lead being reduced to carry down the gold, and the sulphur of the sulphides oxidised at the expense of the oxygen of the red-lead, or of the nitre, as the case may be. To explain all these points properly several lectures would be necessary; but the processes given will, it is believed, be found most useful to the emigrant to Australia who may wish to make himself acquainted with the art of assaying.

Scorification.—This process of assaying ores of the precious metals is very simple, effective, and of general application. It is founded upon the principle that oxide of lead, when melted, has the property of combining with and dissolving silica and various metallic oxides. The ore is reduced to powder and heated in a shallow cup-like vessel with several times its weight of lead free from silver. This vessel is called a "scorifier," and should be made of re-

fractory clay, and be as *compact* in structure as possible, in order to resist the corrosive action of melted litharge. The operation is conducted in a "muffle," at a temperature at or above that of melted litharge. In proportion as the lead oxidises, the foreign metals present, whether in combination with sulphur or oxygen, are attacked and dissolved in the litharge; and at length, on continuing the process for a sufficient length of time, a clear stratum of melted litharge is observed covering a button of lead. As in many cases the lead employed should be eight times the weight of the ore, the button may be reduced to a sixth or eighth of the original lead. The contents of the scorifier should be rapidly poured into a circular ingot-mould, and when cold the adherent litharge may be detached from the button of lead by a few blows on the side with a hammer. This button contains all the precious metals, which may be subsequently extracted by cupellation. By repeating this process upon a fresh portion of ore, mixed with a proper quantity of lead, and introducing the button first obtained, a second button of the same weight as the first may be procured, containing all the precious metals from the two quantities of ore. And by repeating the process, in like manner, the silver and gold present in a large quantity of ore may be concentrated in a small button of lead. In the course of the operation it is occasionally desirable to add a small quantity of fused borax. Before using the "scorifier" some assayers are accustomed to rub over the surface of the cavity with red oxide of iron or hæmatite; and certainly there appears to be no disadvantage in this practice, the object of which is to

prevent the contact of the litharge with the substance of the scorifier, and consequently its corrosive action. Just at the last part of the operation, the heat should be increased so as to render the litharge very liquid. It is convenient to employ the lead granulated, that is, divided by pouring the melted metal in a small stream into cold water. The button obtained should be soft and ductile; and if it is not, either the "scorification" has not been carried far enough, or sufficient lead has not been added.

Cupellation.—The principle and mode of conducting this process on the large scale having already been explained, it now only remains to describe the mode of cupelling by the assayer. It is necessary to remind the reader, that to perform this department of assaying much practice and skill are required. Extreme accuracy in the determination of the proportion of gold especially is obviously of paramount importance, as a minute error becomes enormously multiplied when the quantity in the ton is calculated from an assay of 500 or 1000 grains of ore. The cupel is a little vessel of bone-ash, having a shallow, concave surface. Cupels are of various sizes, so as to be capable of absorbing variable quantities of litharge. The bone-ash is sifted and moistened with water. Instead of water, a slightly glutinous liquid, such as beer, has been long employed by some, and is mentioned in ancient works on assaying. A mould is required to form cupels. It consists of two parts; a short, stout hollow cylinder, either of cast-iron or gun-metal, the diameter of the cavity being somewhat greater at the top than the bottom, and a plunger of the same metal, having the

lower end turned convex, so as exactly to correspond to the concave surface of the cupel, and fitting loosely into the cylinder above mentioned. A sufficient quantity of the prepared bone-ash having been put into the mould, the plunger is introduced and struck several times with a mallet; it is then withdrawn, and the cupel, which is formed, may be readily thus forced out by pressing the lower and smaller end with a cylindrical piece of wood of slightly less diameter. The cupel is then placed in a warm situation to dry. To proceed with the assay. The lead containing the gold or silver is placed upon a cupel, previously heated to the proper temperature in a muffle, and the process conducted in the manner already described. In the cupellation of gold alone, the temperature should be considerably raised towards the latter part of the operation; but it would be well, when the assayer may have reason to know pretty nearly the produce of gold, to ensure the presence of at least two or three times more silver than gold, which can readily be done by the addition of a little fine silver to the lead upon the cupel. As soon as the brightening of the metallic bead is observed, the cupel must be slowly cooled by drawing it towards the mouth of the muffle; but the cooling must not be too rapid, otherwise there may be very sensible loss by spitting. It is occasionally convenient, in order to insure gradual cooling, to invert over the cupel containing the bead another heated cupel. When cold, detach the bead, place it between a pair of strong forceps, so as to leave the lower or flat side free, squeeze gently, to detach adherent litharge from that side,

and clean off the last trace of litharge by a common scratch-brush of brass-wire, or by a very stout bristle-brush. If the operator should at any time require a larger cupel than he may have by him at the time, he may use as a substitute a cupel placed upon another cupel *inverted*. After each cupellation, the surface of the cupel should be carefully examined, to ascertain whether any minute globules of metal have been left. The presence of tin or nickel materially interferes with the process, as neither will pass into the cupel by the aid even of a very large quantity of lead, but will remain on the surface as a sort of slag, in which particles of precious metal may be entangled. In this case the process of scorification may be resorted to with advantage before cupellation.

Although silver is not appreciably oxidised or volatilised when melted alone, yet it is so in cupellation by virtue of the presence of lead. It becomes, therefore, necessary to determine the amount of loss under varying conditions, so as to be able in the calculation of the percentage to add the loss occasioned in the operation. [A table for this purpose is added at the end of the lecture.]

When copper, or other base metal, is present, the proportion of lead added must be regulated by the proportion of base metal. [A table is also added containing the necessary information on this subject.]

Parting.—As has been before stated, in order to dissolve out silver by nitric acid from a given alloy of gold, the weight of the silver must exceed about three times that of the gold. When practicable it is always desirable to have this relation, for if the silver be present in

sensibly greater proportion, then it will not be possible to obtain the gold in a compact form, and the operation will be rendered more difficult. Let there be given an alloy of the kind mentioned. Hammer it flat on an anvil, and roll it out between a pair of small rolls to about $\frac{1}{80}$ of an inch in thickness, from time to time annealing it by heating it to redness and allowing it to cool. Then twist it into a spiral coil, or as it is termed, "cornet." Then put this cornet into a proper parting glass-flask, (which is conical and increasing in diameter from the neck to the bottom,) containing nitric acid *free from chlorine,* and of about 1·2 specific gravity. The acid must always be tested for chlorine, by adding a drop of a solution of nitrate of silver to it, which, if chlorine be present, will instantly render it milky. Heat the flask gently on a sand-bath. Effervescence will take place, and the silver will dissolve, leaving the gold in the form of the original cornet, of a deep blackish brown colour. When effervescence has entirely ceased, carefully decant the solution without letting the cornet of gold fall out. Add a fresh portion of stronger nitric acid and boil. Decant the solution as before, and replace it with distilled water. Renew the water several times, always keeping the cornet in the flask, and at length carefully invert the cornet into a small smooth crucible, and heat gradually to low redness. The gold cornet will thus contract and acquire the characteristic golden colour. Weigh it. If there be more silver than sufficient, or if the particle of gold obtained in assaying is very minute, then the operation of parting and washing must be conducted with extreme care to prevent loss; and

in some cases it may be necessary to use a very small filter and proceed with the usual precaution of the laboratory. The filter will have to be burnt in a porcelain crucible, and the gold weighed in it.

In assaying native gold cut off a piece weighing somewhat more than twenty-four grains. Roll it out. Cut from it two pieces weighing exactly twelve grains, for the purpose of a double assay. Add about three times as much silver to each, and the proper quantity of lead. It is convenient to wrap up the whole in a piece of thin sheet assay-lead. Cupel and part. Gold is always estimated in value in relation to standard gold, which is an alloy of gold and copper in the proportion by weight of 22 to 2. Such an alloy is said to be 22 carats fine. If it contained 23 parts of gold by weight in the 24, it would be 23 carats fine, or 1 carat *better than standard.* If, on the other hand, it contained only 21 carats, it would be 1 carat *worse than standard.* The report of the assayer is always given in relation to standard. Fine or pure gold would be 24 carats fine, that is, there would be no alloy. Hence 12 grains is a convenient weight of gold to assay, as you have to multiply by 2 to determine at once its relation to standard.

The silver contained in the solution of nitrate of silver, obtained in the process of parting, may readily be recovered by various means. One of the simplest is as follows:—Add excess of common salt, which will throw down the whole of the silver as white insoluble chloride, which speedily becomes slate-coloured by exposure to light. Collect this, and put it into a vessel containing water,

acidulated with hydrochloric acid, then introduce some zinc or iron. The silver will thus be rapidly restored to the metallic state in the form of a dark grey powder. Wash this with water; dry it, and fuse it in a crucible with about five per cent of its weight of nitre. The silver thus obtained "spits," and is very brittle; but becomes malleable simply by re-melting. The separation of silver from gold in the large way is generally effected in this country by nitric acid, and the silver recovered as above. The necessary description of apparatus and general appliances would require too much space for this lecture. Sulphuric acid is also very extensively employed on the Continent to effect "parting" on the large scale.

EXPERIMENTS, ETC., REFERRED TO IN THE LECTURE.

1. Auriferous quartz, California. Of "tailings," or quartz, which had been crushed and imperfectly washed, were weighed 600 grains

Carbonate of soda (dry)	600 „
Red lead	500 „
Charcoal	20 „

The mixture was made by trituration. The button of lead obtained yielded by cupellation a globule of gold (containing silver) weighing 0·43 grains, or 23 oz. 7 dwt. 14 grains per ton. After parting by nitric acid, the gold weighed 20 oz. 11 dwt. 11 grains.

2. Of the same "tailings" were weighed .. .. 16 oz.

Red lead	12 „
Carbonate of soda (dry)	12 „
Charcoal	180 grains

The mixture was made by trituration. After exposure to

a high degree of heat a transparent light-green glassy slag was obtained, and a cake of auriferous lead.

3. Of the same "tailings" were weighed .. .. 1200 grains
Lime .. .. 2080 „
Iron ore, containing 2800 grains of sesquioxide of iron, and 1200 grains of silica, and of the value of only five or six shillings per ton, after railway carriage of sixty miles .. 4000 grains
Metallic lead (granulated) .. .. .. 1000 „
Charcoal (to reduce the sesquioxide of iron to the state of protoxide) .. .. 148 grains

These ingredients were mixed by trituration, and the mixture was exposed to a white heat for an hour in a black-lead crucible. The slag thus obtained was well fused, black, and glassy. Some metallic iron was separated.

4. Of the same "tailings" were weighed .. .. 850 grains
Roasted auriferous iron pyrites .. .. 1000 „
Lime .. .. 750 „
Metallic lead .. .. 500 „
Charcoal .. .. 38 „

The mixture was made as before, and similarly treated. The slag was well melted, and of a dull-green colour.

5. 100 parts by weight of sulphide of lead or galena require not less than 23·3 parts of iron to be reduced to the metallic state. It is always desirable to employ a larger quantity of iron than is necessary.
6. 100 parts by weight of red lead require not less than 3·8 parts of charcoal to be reduced to the metallic state.
7. 70 parts by weight of protoxide of iron combine with 30 of silica to form a very fusible slag. It is similar to that generally produced in the iron "puddling" furnace, and called "tap-cinder."
8. About 15 parts by weight of alumina, 38 of silica, and 47 of lime, combine to form a fusible slag, which is similar to that generally produced in the iron "blast-furnaces" of the country, and which is called "blast-furnace cinder."

Table showing the proportions of lead required in the cupellation of alloys of silver and copper in different pro-

portions. The first column represents the weight of silver in 1000 parts; the second the weight of lead required to cupel 1 part by weight of the alloy corresponding in the first column: and the third gives the ratio in weight which must exist between the lead and copper, in order that the former may be perfectly removed by the process of cupellation.

I.	II.	III.
1000	$\frac{3}{10}$	
950	3	60 to 1
900	7	70 „ 1
800	10	50 „ 1
700	12	40 „ 1
600	14	35 „ 1
500	16 to 17	32 „ 1
400	16 „ 17	27 „ 1
300	16 „ 17	23 „ 1
200	16 „ 17	20 „ 1
100	16 „ 17	16 „ 1
Pure copper	16 „ 17	16 „ 1

The following table gives the loss of silver which occurs in the cupellation of alloys of silver and copper in different proportions, and consequently indicates the proportion of silver which must be added in compensation for this loss. The first column gives the weight of silver in the 1000 parts; the second, the actual weight of silver found by cupelling an alloy of silver and copper containing the weight of silver corresponding in the first column; and the third, the actual loss in weight of silver. No special table is requisite for the cupellation of gold, because, for other reasons than those mentioned in a former part of the lecture, it is always desirable that the gold subjected to cupellation should be alloyed with three times its weight of silver. And in this

case the information in the first table will apply, as the alloy of gold and silver to be cupelled may be treated with the same proportion of lead as is required for the silver alone in any given alloy of that metal and copper.

I.	II.	III.
1000	998·97	1·03
975	973·24	1·76
950	947·50	2·50
925	921·75	3·25
900	896·00	4·00
875	870·93	4·07
850	845·85	4·13
825	820·78	4·22
800	795·70	4·30
775	770·59	4·41
750	745·48	4·52
725	720·36	4·64
700	695·25	4·75
675	670·27	4·73
650	645·29	4·71
625	620·30	4·70
600	595·32	4·68
575	570·32	4·68
550	545·32	4·68
525	520·32	4·68
500	495·32	4·68
475	470·50	4·50
450	445·69	4·31
425	420·87	4·13
400	396·05	3·95
375	371·39	3·61
350	346·73	3·27
325	322·06	2·94
300	297·40	2·60
275	272·42	2·58
250	247·44	2·56
225	222·45	2·55
200	197·47	2·55
175	173·88	2·12
150	148·30	1·70
125	123·71	1·29
100	99·12	·88
75	74·34	·66
50	49·56	·44
25	24·78	·22

FURNACES.

Reverberatory.—Annexed is a drawing, in section and plan, of a reverberatory-furnace at the copper works of Swansea.

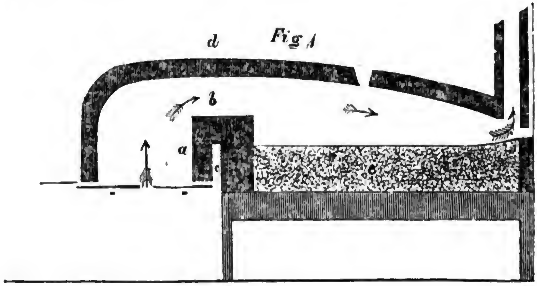


Fig. 1. Longitudinal section :—

a. The fireplace.

b. The fire-bridge.

c. A space left hollow, so that air may circulate through and the bridge be kept cool.

d. The roof of the furnace.

e. The bed of the furnace, which in this case is made of sand.

f. An opening in the roof, through which material may be introduced.

g. An opening at the end, from which slag may be skimmed, &c.

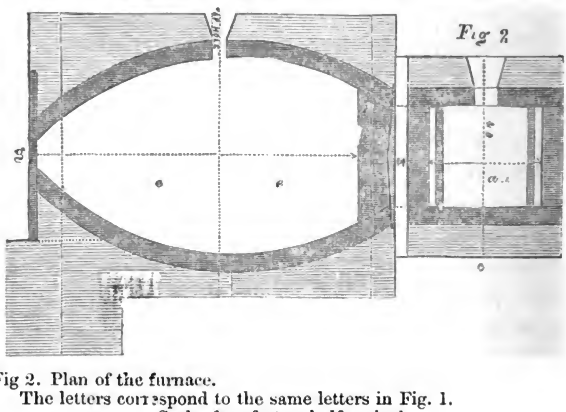
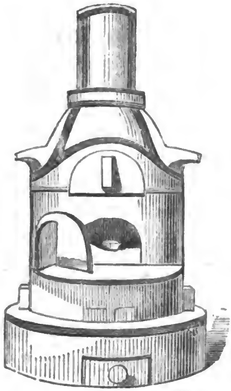


Fig 2. Plan of the furnace.

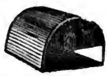
The letters correspond to the same letters in Fig. 1.

Scale, four feet to half-an-inch.

Muffle furnace and Muffle.—Annexed is a drawing of a convenient furnace of this kind for performing the operations of cupellation and scorification. It is similar to that used at the Mint in Paris. It is very portable, and consists of three parts, which may be adjusted upon each other, as seen in the drawing. The muffle, which is shown *in situ*, is a small



Muffle Furnace.



Muffle.

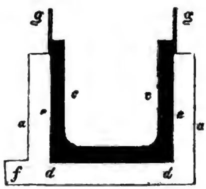
chamber of fire-clay, open at one end, and of the shape represented. There are small apertures either at the end or sides, so that a current of air may be drawn through. The dimensions of the muffle are as follow:—Diameter, $5\frac{3}{4}$ inches; width, $5\frac{1}{4}$; height, $3\frac{3}{4}$; thickness, $\frac{1}{4}$.

The French muffles are very thin, and consequently enable the operator quickly to regulate the temperature by opening or closing the aperture above the muffle through which the fuel is introduced. The fuel should be charcoal. The furnace itself is made of refractory clay, bound by pieces

of hoop-iron. Messrs. Knight, of Foster Lane, have an extensive collection of good portable furnaces; and Mr. Newman, of Regent Street, also manufactures a convenient furnace of this kind.

Small portable blast furnace, which may frequently be used with advantage.

Annexed is a sketch of a furnace of this kind, which was devised by my friend, Mr. Ekman of Gottenburg, in Sweden, for the assaying of iron ores. It is nothing more than a small Sefström's furnace. Fashion two pieces of stout sheet-iron into the form of a common hat, and make one of these



a a Outer cylinder.
b b Inner cylinder.
c c Fire-clay lining.
d d Space between the two vessels.
e e Openings for the passage of air.
f Tube connected with the bellows.
g g Movable hoop of iron.

vessels smaller than the other; then invert the small one into the large one, and fasten the rims together. There is thus formed between the two vessels an air-tight chamber. Into the outer one fix at the bottom a piece of tubing of sheet-iron, which may be connected with a pair of double bellows, or a common fan-blast, such as is commonly sold in the shops for a few shillings. Make eight holes of $\frac{3}{4}$-inch diameter in the central vessel, and at three inches from the top. Line this vessel with fire-clay, half-inch thick, through which makes holes corresponding to those in the iron vessel. Thus, by blowing into the tube at the bottom of the outer vessel,

the air is forced into the central chamber through eight holes. By this means a very high temperature may be obtained, sufficient, if need be, to melt manganese. Around the top of the central chamber place a hoop of sheet-iron of two inches wide, so as to form an additional space for fuel. The ends of this hoop are left free, and may be brought together and fastened in any convenient manner. When not in use, the hoop may be placed round the outside of the furnace for the sake of portability. Charcoal must be employed as fuel, and should be broken in pieces about as large as the end of the thumb. The dimensions of the furnace are as follow:—Height, 6 inches; diameter, $7\frac{1}{4}$; interior cylinder, $5\frac{3}{4}$; depth, $5\frac{1}{4}$. Fire-clay, thickness $\frac{1}{2}$ inch; holes, 3 inches from the top of interior cylinder; iron hoop, 2 inches wide.

Crucibles.—Black-lead crucibles consist of a mixture of plumbago and refractory clay.

Fire-brick and clay crucibles may be made of a mixture of burnt and unburnt clay, in the proportion of about one measure of the former to two or three of the latter. The use of the unburnt clay is to diminish contraction, and so prevent cracking.

The most convenient size of the Cornish crucible, of which a sketch is annexed, is $3\frac{1}{2}$ inches deep (outside measure), and 3 inches diameter at the top. These crucibles are invaluable, and bear sudden and great alternations of temperature without cracking.

Cupels.—Annexed is a drawing of the mould which has

previously been described, and of the tongs which may be used in this process. Cupels may generally be considered as

Cupel.

capable of absorbing their own weight of lead. Dimensions of mould:—Interior diameter at top, $1\frac{9}{16}$ inch; interior diameter at bottom, $1\frac{8}{16}$; depth, 2 inches.

Scorifiers.—Convenient dimensions are as follow:—Diameter at top, 2 inches; height, $\frac{7}{8}$; interior diameter, $1\frac{7}{8}$; depth, $\frac{1}{2}$.

Ingot Mould.—Dimensions: Length, $5\frac{1}{4}$ inches; width, $2\frac{1}{4}$;

depth, 1; diameter of cavities, $1\frac{5}{8}$; depth, $\frac{6}{8}$.

Parting-glass Flask.

LIST OF APPARATUS AND MATERIALS REQUIRED.

Balances, one for weighing roughly comparatively large quantities, and a delicate assay balance. Crucibles, various. Ingot-mould. Tongs, for crucibles, scorifiers, and cupels. Assay furnace and muffles. Scorifiers. Cupels. Copper Scoop. Anvil. Hammer. Small pair of rolls. Small cutting shears and scissors. Chisels for cutting off pieces of metal. Forceps. Files, flat and three-cornered. Scratch-brushes. Parting-flasks. A few stoppered bottles and funnels. Assay lead, free from silver, granulated and rolled thin. Red lead. Carbonate of soda (dry). Borax (dry). Nitre. Nitric acid, pure.

Messrs. Knight, of Foster Lane, have always on hand an extensive and excellent assortment of assaying apparatus.

LECTURE VI.

THE HISTORY AND STATISTICS OF GOLD.

BY

ROBERT HUNT, Esq.

KEEPER OF THE MINING RECORDS.

ROBERT HUNT, Esq.

ON THE

HISTORY AND STATISTICS OF GOLD.

It may appear to many that a Lecture on the History and Statistics of Gold must prove of but little value for those who are about to try their fortunes in a new land, who are looking eagerly forward to the realisation of property, either directly, by searching for the precious metals; or indirectly, by availing themselves of the new circumstances which must of necessity arise. That these may be points of interest they are, perhaps, ready to admit, but they scarcely apprehend the utility of the consideration.

When first a wish was expressed that, as Keeper of the Mining Records in this establishment, I should undertake a lecture on the history and statistics of gold, I felt some difficulty; but a careful consideration of the subject has led me to believe that I can be of a little service. I shall be enabled, I hope, to show you, by the historical evidences which we possess, that there is an order in the respective discoveries of gold deposits which approaches to

something like a law of distribution; and the study of the facts which history affords must lead to the inference that it is improbable any very extensive commercial changes will arise from the discovery of extraordinary quantities of gold in Australia, California, or elsewhere. Moreover, from a knowledge of what has been, we may infer, with much probability, what will be; and I believe the history of gold-finding will show that modern El Dorados, like those of old, are not likely to yield unlimited supplies; and thus an advantage will be gained in checking the extreme hopes of the sanguine, and dividing the attention of industrious emigrants between the sources of wealth always earned with difficulty in the gold-field, and those yet more important sources of individual happiness and national prosperity, which are to be found in the legitimate occupations of the artisan, and the quiet pursuits of the agriculturalist.

Many fears have been expressed lest the great influx of gold into this country should produce a considerable difference in its value. It will be evident to all, that if gold, instead of being worth four pounds an ounce, as it is at present, should, from some extraordinary supply, suddenly fall to three pounds an ounce, that every man possessed, say of one hundred sovereigns, would find their value sunk to 75*l.*; and those who had incomes, say of 400*l.* per annum, would discover to their sorrow that they could only realise 300*l.* worth of any other article which the necessities of their existence might require in exchange for gold. The question appears to have been very seriously entertained by many able writers; amongst others, by the

author of the money articles in the "Times" of June 25. Now, it is not my intention to enter into this question; but I believe I have obtained some data to show that there are opening out sources through which any quantity of gold likely to be discovered may be diffused to the production of much good, obviating the necessity for that change in its value so much dreaded by some. Without further prefatory remarks, I will at once enter on my sketch of the history of that metal which now engages attention.

A slight consideration of the circumstances under which gold is found will sufficiently explain its very early discovery by man. Gold differs remarkably from the other metals, with a very few exceptions, in the fact, that it is found in nature in its metallic state. Iron and copper, tin, lead, and silver, are ordinarily discovered in chemical combination with oxygen, sulphur, arsenic, or carbon; and the few exceptional occurrences of these metals in an uncombined, or, as it was formerly called, virgin state, are to be cited rather as mineralogical curiosities than as common productions. Gold is, however, always found native or metallic, and even in those cases where we find this precious metal disseminated through masses of oxide of iron, and sometimes of sulphurets of iron and copper, it is probably in a state of mechanical mixture, and not in chemical combination. Therefore, as a metallic mass, curious by its yellow colour, it would attract the eye of the most uneducated man, whereas the other substances likely to lie in his path would offer no features of attraction to his scarcely awakened powers of observation.

Again, as you have learned from the previous lectures, gold, from the circumstance of its having been formed in those rocks which are most exposed to atmospheric action, is found in the *débris* of the mountains. By the disintegrating influences, of the atmosphere, of changes of temperature, of the action of water, and particularly by the effects of ice, fragments of rock are continually broken off. These are borne by floods into the valleys and rolled into pebbles by the constant action of flowing water. Amongst these, pebbles, or particles, of gold are discovered. The summer heats, by drying up the waters, rendered those beds which had formed river channels and the courses of winter torrents, paths for the journeys of migratory man; and here we can easily imagine the early discovery of gold. It was, of course, in the first instance, used in its pure or native state, in the same way as it is at the present day employed by the inhabitants of Africa. Certain it is that gold must take its place as the earliest metal known, and in the first records of man's progress it is indicated as a standard of man's position. The sacred historian speaking probably of the Euphrates as the river *Pison,* says it "encompasseth the whole land of Havilah, where there is gold, and the gold of the land is good." Of Abraham we are told "he was rich in cattle, and in silver and in gold." Again, in that exquisitely beautiful sacred poem, the book of Job, written probably by a contemporary of Abraham, we read those remarkable words, "Surely," says he, "there is a vein for the silver and a place for the gold where they fine it." From this we learn that metallic veins containing silver and gold had been discovered and worked. Job

subsequently informs us "that the earth hath dust of gold," showing that he was familiar with the fact of the distribution of gold in sands and soils. Up to this period it does not appear, however, that gold was used as money, as we find both it and silver passing from hand to hand by weight. When, however, after his trial the wealth of Job was restored in addition to the cattle and the money which his visitors brought him, we have the very interesting piece of information, that each of them brought also an *earring of gold,* thus proving the use of this metal at that time as a personal ornament. Specimens of similar rings, usually called *ring-money,* have been found in the bogs of Ireland, some of which are in the Museum of Practical Geology; and the Africans, at the present day, manufacture rings and armlets of a similar shape in gold.

From the sacred writings we also gather some facts of importance as regards the use of manufactured gold. It must have been beaten into thin plates at a very early period, as we are told "the ark of shittim-wood was covered with gold, both on the outside and the inside," as were also the "staves," the "wooden table with its staves," the altar of burnt-incense, and the boards which formed the sides of the tabernacle.

Herodotus informs us that the Egyptians were accustomed to gild wood and metals; and we learn that Solomon caused various parts of the Temple to be overlaid with gold, and more particularly, the doors of the oracle, in which were carved cherubim, palm-trees, and open flowers; thus showing that gilding was applied by the Hebrews to ornamental decoration, as we apply it in the present

day. Beckmann, in his "History of Inventions," says, "The Hebrews probably brought the art of gilding with them from Egypt, where it seems to have been very old, as gilding is found not only on mummies, the antiquity of which indeed is uncertain, but, if I am not mistaken, in the oldest temples on images. It appears, also, that in the time of Moses the Hebrews understood both the art of gilding and of overlaying with plates of gold." The researches of the chemist indicate a knowledge even beyond this. On a mummy recently unrolled the name was found written in an indelible ink; this ink was found, by analysis, to contain silver, and, from the action on the linen cloth, the inference is that it was dissolved in nitric acid, that it was, in fact, identical with the permanent marking-ink of the present time. This certainly indicates an advanced state of chemical science; and if the Egyptians, possessing nitric acid, also had the means of liberating muriatic acid from their salts, either of soda or ammonia, they would have the materials necessary for the solution of the golden calf which Moses destroyed. This may, however, have been a gilded figure merely, and destroyed by grinding to powder, and nothing more.

In the history of gold we must not fail to remark particularly the periods when it appeared to have been accumulated in great abundance. The reign of Solomon appears to be the first of which we obtain any authentic account. That Hebrew king collected in a single year six hundred threescore and six talents, or, perhaps, about 300,000*l.* in value of our present money; we learn also that the ships of the king brought from Ophir 420 talents

of gold, or 190,800*l.* The language in the book of Kings is as follows, "His throne was of ivory, overlaid with the best gold, that all the drinking-vessels were of gold, that all the vessels of the house of the forest of Lebanon were of pure gold; none were of silver, for that metal was nothing accounted of in the days of Solomon;" and, in short, "the king made silver to be as stones in Jerusalem."

Ninus, the founder of Nineveh, is said by Diodorus to have "possessed himself of all the treasures of Bactriana, among which was abundance of gold and silver;" and the same author informs us that Semiramis, the founder of Babylon, erected statues of beaten gold,—that of Jupiter being forty feet in height and weighing a thousand Babylonian talents, and those of Rhea and Juno equalling it in size and magnificence. From the accounts given by Diodorus it is inferred that Semiramis had collected as much gold as would amount to 11,000,000*l.* of our own money.

Darius, king of Persia, about 480 years before the Christian era, drew tribute in gold from the several provinces into which his kingdom was divided, which amounted, according to the calculation of Gibbon, to 3,250,000*l.* sterling. We learn from Herodotus the curious fact, that "the gold and silver were melted and poured into earthen vessels, and these when filled were removed, leaving the metal in a solid mass; when any was wanting, a piece was broken off of the capacity which the occasion required."

The wealth of Crœsus, king of Lydia, who lived 540

years before Christ, has become proverbial. The presents which he made to the temple of Delphi amounted to 4000 talents of silver and 270 talents of gold, which is nearly equal to 3,000,000*l.* sterling. The following story from Herodotus is instructive,—it illustrates the wealth of the king, and the manners of the time:—"When Crœsus sent his Lydians from Sardis to consult the oracle at Delphi, they were received with hospitality by the family of the Alcmæonidæ at Athens, and, on their return, acquainted their master with the kindness they had experienced. A member of that family received an invitation to visit Crœsus, and on his arrival was presented with as much gold as he was able to carry. To improve the value of the gift, Alcmæon made use of the following artifice:—Providing himself with a large tunic, in which were many folds, and with the most capacious buskins he could procure, he followed his guide to the royal treasury; there, rolling himself among the golden ingots, he first stuffed his buskins as full of gold as he possibly could; he then filled all the folds of his robe, his hair, and even his mouth, with gold dust. This done, with extreme difficulty he staggered from the place; from his swelling mouth and projections all around him, resembling anything rather than a man. When Crœsus saw him he burst into laughter, and not only suffered him to carry away all he had got, but added to it other presents equally valuable. The family from this circumstance became exceedingly affluent, and Alcmæon was enabled to procure and maintain those horses which gained him the victory in the

Olympic games." From this story we learn the important fact that the wealth of Crœsus was principally in gold as found in nature.

In the consideration of our subject, the story of Pytheus is of much importance. He is said by Herodotus to have entertained Xerxes and his whole army, and when asked the amount of his wealth, to have replied to that monarch,—

"I conceal nothing from you, and will not affect ignorance, but fairly tell you the whole. As soon as I heard of your approach to the Grecian sea, I was desirous of giving you money for the war. On examining into the state of my affairs I found I was possessed of 2000 talents of silver, and 4,000,000, wanting only 7000, staters of gold of Darius." These metallic treasures have been estimated at 3,600,000*l.* of our money. Pytheus kept the whole of his subjects and slaves searching and mining for gold, until at length, through the want of food, he was induced to order that one-fifth instead of the whole should in future be compelled to devote themselves to these operations. This amelioration appears to have been due mainly to the intercession of his wife, that lady regretting that her husband's thirst for gold should lead to the sacrifice of the lives of his subjects. It appears from this that wealth was only amassed by petty despots, who did not hesitate to condemn all the subjects of their states to the slavery of mining.

Pericles, to animate the Athenians in their defence against the Peloponnesians, stated the money in the citadel to be 1,162,250*l.*, and in addition, that the gold

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in the statue of Minerva, which if appropriated by the public must be replaced, amounted to 124,800*l.*, and that the revenues from tributary states amounted annually to 116,250*l.* We thus form a tolerably correct idea of the wealth of Athens at the time when the illustrious Pericles presided over its destinies.

Numerous instances might be quoted to show the wealth of individuals in Egypt and Greece; but it is scarcely necessary to do this, since we cannot arrive thereby at any very correct idea of the amount of gold existing in these countries. In the time of Ptolemy Philadelphus, it is stated by Appian that the Egyptian treasury contained no less a sum than 178,000,000*l.* This was obtained by collecting with an armed force all the silver and gold of the people; and this armed force was not the regular army, but organised bands of robbers.

The Romans possessed immense wealth, as might be expected from the character of the people and their immense possessions. We learn that Augustus obtained by the testamentary disposition of his friends 32,291,666*l.* sterling; and Tiberius left at his death the enormous sum of 21,796,875*l.* sterling, which Caligula is said to have squandered in a single year.

Vespasian, at his accession, estimated the money which the maintenance of the commonwealth required at 322,916,000*l.*

Pliny commences a chapter on gold:—"Oh! that the use of gold were clean gone. Would God it could possibly be quite abolished among men, setting them, as it doth, into such a cursed and excessive thirst after it—if

I may use the words of most renowned writers—a thing that the best men have always reproached and railed at, and the only means found out for the ruin and overthrow of mankind. What a blessed world was that, and much more happier than this wherin wee live, at what time, as in all the dealings between men, there was no coin handled, but their whole trafficke stood upon bartering and exchanging ware for ware, and one commodity for another; according as the practice was in the time of the Trojan war, as Homer (a writer of good credit) dooth testifie."

When we read of the extreme extravagance of the Roman emperors and consuls, we can well understand the application of this. Cæsar, before he set out for Spain, is stated to have been 2,018,000*l.* in debt. He is reported to have bribed Curio with 484,370*l.*, and the consul Paulus by 279,500*l.*

Anthony, on the Ides of March, when Cæsar was killed, owed 320,000*l.*, which he paid before the Kalends of April out of the public money; and squandered, according to the statement in Adams' "Roman Antiquities," more than 5,600,000*l.* The manufacture of gold appears to have been carried to a great degree of refinement among the Romans. From Pliny we learn that gold was beaten to such a degree of thinness that one ounce of gold was extended to 750 leaves, each four inches in size. Lucretius compared the Roman gold-leaf to a spider's web; and Martial described it as little other than a vapour. It is not uninteresting to learn from the German monk, Theophilus, that the process of gold-beating was similar to that now practised; the thin gold

being beaten between leaves of parchment, which was covered with burnt ochre in very fine powder, to prevent the gold from adhering to the skin. Pliny informs us that gold-leaf was applied to marble with a varnish, and to wood with a cement called *leucophoron.* This author also describes with great accuracy the process of gilding, by combining the gold with mercury, and volatilizing the latter metal by heat.

Up to the time of Augustus the wealth of the world appeared to flow into the lap of Rome, when the production of gold from the Roman mines in Illyria and Spain suddenly ceased; and for a long period the world received no new accession of metallic wealth. Jacob has, with much research, constructed a table showing us the rate of diminution to which the enormous wealth of the Augustan period was subject. It is a curious and instructive compilation :—

QUANTITY OF GOLD AND SILVER IN THE ROMAN EMPIRE.

Year.	£	Year.	£
14	358,000,000	446	96,692,332
50	322,200,000	482	87,033,099
86	287,980,000	518	78,229,700
122	259,182,000	554	70,406,730
158	233,263,800	590	63,364,057
194	209,937,420	626	57,027,652
230	181,943,678	662	51,324,887
266	163,749,311	698	46,192,399
302	147,374,380	734	41,573,160
338	132,636,942	770	37,415,840
374	119,373,248	806	33,674,256
410	107,435,924		

To assist us in our inquiry as to sources from which the ancients obtained their gold, the following remarks from the "Cosmos" of Humboldt will be found valuable, relating as they do to the progress of navigation among the Greeks :—

"Whatever doubts may remain as to the particular locality of the distant 'Gold Lands,' Ophir and Supara,—whether these gold lands were on the west coast of the Indian Peninsula, or on the east coast of Africa,—it is not the less certain that this active Semitic race, early acquainted with written characters, roving extensively over the surface of the earth, and bringing its various inhabitants into relation with each other, came into contact with the productions of the most varied climates, ranging from the Cassiterides to south of the Straits of Bab-el-Mandel, and far within the region of the tropics. The Tyrian flag waved at the same time in Britain and in the Indian Ocean. The Phœnicians had formed trading settlements in the most northern part of the Arabian Gulf; in the harbours of Elath and Ezion Geber, as well as in the Persian Gulf at Aradus and Tylos, where, according to Strabo, there were temples similar in their style of architecture to those of the Mediterranean. The caravan trade, which the Phœnicians carried on in order to procure spices and incense, was directed by Palmyra to Arabia Felix, and to the Chaldean or Nabathaesi Gerrha, on the western or Arabian shore of the Persian Gulf.

"The expeditions of Hiram and Solomon, conjoint undertakings of the Tyrians and Israelites, sailed from Ezion Geber through the Straits of Bab-el-Mandel to

Ophir. Solomon, who loved magnificence, caused a fleet to be built in the Red Sea, and Hiram supplied him with Phœnician mariners well acquainted with navigation, and also Tyrian vessels, 'ships of Tarshish.' The articles of merchandise which were brought back from Ophir were gold, silver, sandal-wood, precious stones, ivory, apes, and peacocks. The researches of Gesenius, Banfey, and Lassen, have made it extremely probable that the western shores of the Indian Peninsula were visited by the Phœnicians, who, by their colonies in the Persian Gulf, and by their intercourse with the Gerrhans, were early acquainted with the periodically blowing monsoons. Columbus was even persuaded that Ophir (the El Dorado of Solomon), and the mountain Sopora, were a part of Eastern Asia—of the Chersonesus-Aurea of Ptolemy. If it seem difficult to view Western India as a country productive in gold, it will be sufficient, without referring to the 'gold-seeking ants,' or to Ctesias' unmistakable description of a foundry, in which, however, according to his account, gold and iron were welded together, to remember the vicinity of several places notable in this respect. Such are the southern part of Arabia, the island of Dioscorides (Diu Zokotora of the moderns, a corruption of the Sanscrit Doissa Sukhatara), cultivated by Indian settlers, and the auriferous east African coast of Sofala. Arabia, and the island just mentioned to the south-east of the Straits of Bab-el-Mandel, formed for the combined Phœnician and Hebrew commerce intermediate and uniting links between the Indian Peninsula and the east coast of Africa. Indians had settled on the latter from the earliest times, as on a shore opposite to

their own, and the traders to Ophir might find in the basin of the Erythrean and Indian seas other sources of gold than India itself."

Herodotus informs us that the people living near the sources of the Indus obtained a large quantity of gold from the eastern border of the great Bactriana, and the desert steppes of Cobi. Much was obtained by washing sands, and more by digging; and both Herodotus and Pliny tell us a strange story of gold being turned up by enormous ants "not so large as a dog, but bigger than a fox," and that from these ant-hills the Indians obtained the greatest quantity, which they supplied to the monarchs of Persia. Humboldt has shown that this story arises from the double meaning of a word. Herodotus, again, tells us that "in the north there is a prodigious quantity of gold, but how it is produced I am not able to tell you certainly. It is affirmed, indeed, that the Arimaspi, a people who have but one eye, take the gold away by violence from the griffins;" but, says the father of history, "I can never persuade myself that there are any men who, having but one eye, enjoy in all other respects the nature and qualities of other human beings."

Pallas, in his Travels, describes the remains of these mines; they were also visited by Lepechin and Gmelin, on the south-eastern borders of the Ural Mountains. They were the work of a nomadic people, in all probability the Scythians. The following descriptions of these old gold works on the Uralian chain, chiefly from Gmelin's Travels, are of much interest, particularly as this gold-

producing region still continues to yield treasure to the efforts of industry.

The extent of the works show that the workmen must have been numerous, whilst an inspection of them proves that only the first rudiments of the science of mining could have been known to them. Besides some implements the use of which is unknown, there were wedges and hammers, all of copper, that had been smelted, but without any particle of gold in them. Instead of sledges, they seem to have used large stones of a long shape, on which are to be seen marks which show that handles had been fastened to them. They seem to have scraped out the gold with the fangs of the boars, and collected it in leather bags or pockets, some of which have been found. With such imperfect implements, the work of excavation must have required the labour of a great number of hands for a long time, and in some cases must have exhausted their patience. In one instance, after having proceeded to some depth, and reached a bed of hard stones, the work, after penetrating a little way, had been abandoned. Some of the pits are twenty fathoms in depth, shaped like a bell, and are about seven feet in diameter. The passages and props are well executed, but the former so narrow and low that it must have been difficult to have worked in them. The natural pillars left to support the roofs are in some instances still effectual for that purpose, and in these are still found small portions of copper ore, containing particles of gold; in other instances the supports have given way, and in them are

found some human bones, probably of those who had been buried in the ruins. That a great number of people were employed, is inferred from the numerous fragments of earthenware which are found scattered to a great distance around. It appears that only the richest ores were worked, and some of them must have been smelted in the mines; for in the rubbish of one of the supports which had fallen in there have been found melted copper, and the implements for smelting it. Some of these implements also have been found on the surface near the pits. The operation of crushing as well as washing the ores was performed in the rivulets, and, as is supposed, the latter was omitted in the rich ores, which were found on elevated spots. The smelting, whether in the mines or on the surface, was performed in small furnaces, of which Gmelin observed near a thousand in the eastern parts of Siberia. They were made of red bricks, and in them pieces of melted copper, from two to three pounds in weight, have been found. The height and breadth of these furnaces were about two feet and the length three feet. There were holes on both the front and back sides, but which of them was appropriated for the bellows could not be discovered by any marks. In the neighbourhood of these furnaces there are large heaps of scoriæ; but no one has had the curiosity to ascertain what metals, if any, they contain. It may be presumed that a long period must have elapsed since the works were in activity, for the roots of large fir-trees have spread themselves among the stones that are heaped against the sides of the furnaces.

It is evident much gold was produced from the mines of Nubia and Ethiopia. These mines, like those of the Uralian chain, produced a copper yielding gold, which the Africans knew how to separate. Belzoni discovered that a very extensive tract had been worked in the Sahara mountains: from these sources the Pharaohs derived their wealth, which was, however, obtained at much human suffering, and immense cost of human life. Jacob, from a very close examination of the subject, is led to infer that not less than 6,000,000*l.* sterling of the precious metal must have been produced annually from those mines; and a large proportion of this appears to have been gold. This may, therefore, be regarded as another source from which gold has been obtained, and spread with advancing civilisation over Europe and Asia. Commencing the history of the ancient gold-seeking with a quotation from Pliny, I will venture to extract another from Diodorus with reference to these Ethiopian mines:—"Nature teaches us that gold is obtained by labour and toil, is retained with difficulty, creates everywhere the greatest anxiety, and its use produces both pleasure and grief."

There were rich silver mines in Attica; gold mines in Thrace and in the island of Thasus. Thessaly produced ores which were rich in gold; and Epirus rich silver mines. From these sources the Athenians drew their wealth.

The Romans obtained their wealth from various sources—Upper Italy, the province of Aosta, the Noric Alps, Illyria. From this district, at one period, gold was abundantly obtained—partly in large grains on the

surface, and partly in mines, so pure that an eighth part only was lost in the processes of smelting and refining. Its great quantity caused a decrease of one-third in the price through all Italy, and induced the proprietors to employ fewer workmen in order to raise the value. The Tarbelli, a people at the foot of the Pyrenees, also streamed extensively for gold.

The discovery of gold in our country requires some brief attention. The Romans were incited to the conquest of Britain by the reported wealth of its inhabitants in gold and other metals; and Cæsar, in his Commentaries, says, that one reason of his invading the Britons was, because they assisted the Gauls with their treasures.

Cimboline, prince of the Trinobantes, which included Essex, is stated to have coined gold money instead of rings; it having been the usual custom to coin such rings as are found in the bogs of Ireland. Of this, Sir John Pettus says in his "Fodinæ Regales," "This was probably the mine afterwards discovered in the time of Henry IV." This is not correct. Instead of any such mine being found, Henry IV., by his letters mandamus, commands Walter Fitz Walter (upon information of a concealed mine in Essex) to apprehend all such persons as he in his judgment thinks fit, that do conceal the said mine, and to bring them before the king and his council, there to receive what shall be thought fit to be ordered.

The Welch Triads celebrate princes as being possessors of golden cars; and in all probability this induced the Romans to penetrate into the principality. That the Romans worked the Gogofau or Ogafau mine for gold,

near Pampsant, Caermarthenshire, has been clearly proved by the investigations of my colleague, Mr. Warington Smyth. A Roman station is indicated by the remains of pottery and ornaments found on the spot. Several gold ornaments, and a very beautifully-wrought gold necklace, probably manufactured in the locality, are in the possession of the owners of the property. Mr. Smyth finds in the characteristic features of the workings on the quartz lodes at Ogofau, the same distinguishing features of Roman industry as mark the Roman mines of Transylvania.

Small quantities of gold have been picked up in Cornwall from the earliest times, particularly in the tin stream works; and in the reigns of Edward I. and III. there were considerable works at Combmartin in Devonshire; between 300 and 400 miners being sent for out of Derbyshire, were employed in them; and the produce was so considerable as to assist the Black Prince in his wars against France. In the reign of Henry III. a copper-mine, which was worked at Newlands, in Cumberland, is said to have contained veins of gold as well as of silver. The Patent Rolls in the Tower record several grants, made by the sovereign to individuals, of privilege to search for gold and silver. In 1390 Richard II. granted to John Younge, refiner, all the gold and silver found in any mine in England, paying to the crown a ninth part, to the Church a tenth, and to the lord of the soil a thirteenth part. It may be here mentioned, as indicative of the spirit of occult philosophy which prevailed in those times, that in 1444 a patent was granted to

John Cobbe, "That, by the art of philosophy, he might transform imperfect metals from their own proper nature, and transmute them into gold or silver."

Pennant says, "In the reigns of James IV. and V. of Scotland, vast wealth was procured in the Lead Hills, from the gold washed from the mountains; in the reign of the latter, not less than to the value of 300,000*l.* sterling. In another locality, the Scotch explorers, we are told, found a piece of thirty ounces weight: there were works in several places; but these, if not exhausted, have long been abandoned. About the year 1796, considerable excitement was produced in Great Britain by the discovery of some large specimens of virgin gold in alluvial soil in the county of Wicklow, in Ireland, and metal to the value of 10,000*l.* was obtained; but the cost of the labour is said to have exceeded that sum. One of the masses weighed twenty-two ounces, and was supposed to have been the largest specimen of native gold ever discovered in Europe; which, however, would not have been correct, if we may credit the accounts of the Scotch specimen mentioned above.

The Hungarian gold mines do not appear to have been worked before the eighth century, and the mines of Sweden and Norway not until a still later date. During the middle ages we find evidences of a continued production of gold, particularly in the gifts to the monasteries, abbeys, and churches; but, the probability is, that from the period when the Romans caused gold to be sought for diligently in all parts of the world unto the discovery of the New World by Columbus, the portion of gold added to

that already obtained was only sufficient to supply the annual waste by wear, &c. Of silver the supply appears to have been larger, hence we read of enormous votive offerings in the shape of silver doors, candlesticks, altar-rails, and images.

In 1492 Columbus discovered America; the first natives he met in Hispaniola had ornaments of gold about their persons. At first Columbus thought he had arrived in Asia, and as this was considered in those days to be the land of gold, the great navigator and his companions formed the most exaggerated ideas of immense treasures with which their toil was to be rewarded. Washington Irving informs us in his "History of Columbus," that an Indian gave a handful of gold-dust for one hawk's bell. The gold obtained from the Indians appears to have been always small, and procured by washing, since Peter Martyr records as a remarkable fact the discovery of a lump of gold weighing nine ounces.

After twelve years' occupation of Hispaniola, the Spanish governor required each individual native above fourteen years of age to pay every three months a Flemish hawk's bell of gold-dust, equal to about twenty shillings in silver of the present day; and the Caciques were, many of them, called on to send to the Spanish treasury as much as ten pounds weight of gold in three months. For those interested in the progress of the discovery of gold in the new continent I must refer to Mr. Irving's "Columbus," and to the "Voyages of the Companions of Columbus." We learn from Humboldt that from 1492 to 1500, America furnished to Europe gold and silver of the value of 52,000*l.*

Orando, in 1502, despatched about 70,000*l.* worth; but most of his ships were wrecked, and but little of this reached Spain. To 1519 the annual produce of gold was never greater than 52,000*l.* Cortez at this period conquered Mexico, and he obtained at Chalco, as presents to himself, 70,000*l.* sterling, in gold. Montezuma, when he took the oath of fidelity to Spain, paid 65,000*l.* worth of gold into the chest of the army. And Bernal Diaz says, that on taking Tenochtitlan, 80,000*l.* fell into the hands of the Spaniards.

Pizarro landed in Peru in 1527, and in the twenty-five years which elapsed between this and the discovery of the mineral wealth of Potosi, America forwarded to Spain, according to the careful calculations of Humboldt, 630,000 pounds' worth of gold per annum; thus the produce of gold in the sixty-three years which followed the discovery of America, amounted to 17,058,000*l.* sterling. The mines of Potosi were discovered in 1545 by an Indian, and in twenty-one years the produce of silver was 29,185,990 pesons; this was equivalent to an annual produce of 280,000*l.* sterling. You perceive when we examine with care the romantic statements of the enormous wealth of the nations of America, that they sink into comparatively humble figures. Europe was agitated by the discovery of Potosi in a similar manner to the agitation produced by the discovery of gold in California; and in many respects the Spanish nation then exhibited a similar degree of excitement to that produced by the discovery of gold in Australia among ourselves.

From careful calculations made by Jacob, from mate-

rials furnished by the Spanish writers and by Humboldt, it would appear that the sum which formed the stock of money current in Europe at the latter end of the sixteenth century would be composed of the stock existing at the time of the discovery of America,—

Equal to	£34,000,000
That produced in the 112 years, after making allowance for the loss by natural wear ..	138,000,000
	£172,000,000
Deduct from this what had been conveyed to Asia, and what had been applied to purposes of commodities of all kinds ..	42,000,000
	£130,000,000

the stock of gold and silver coin in Europe at the end of the year 1599.

Of the discovery of gold in Brazil a few words must suffice.

Dr. Walsh says gold was first known to exist in the Brazils in 1543. The Indians made their fishing-hooks of it, and from them it was discovered that it was found in the beds of streams, brought down from the mountains. But the first ore found by a white man in that country was in the year 1693; this discovery led to the colonization of the Minas Geraes, and to all those evils resulting from the "cursed lust of gold," with details of which the history of South America abounds.

Dr. Walsh mentions that, at a very early period, "two parties meeting on the banks of the river, where San José was afterwards built, instead of agreeing in their objects, and pursuing together their operations, set upon each

other like famished tigers, impelled by a hunger still more fierce—the *auri sacra fames*. A bloody encounter ensued, in which many were killed on both sides, and the river was from thenceforth called the Rio das Mortes, or the River of Death." "The vicinity of this river," proceeds our authority, "everywhere attests the extensive search for gold formerly pursued here, as it was for a length of time considered one of the richest parts of Brazil, from the profusion of the precious metal found on its surface. All the banks of the stream are furrowed out in a most extraordinary manner, so as to be altogether unaccountable to one unacquainted with the cause. The whole of the vegetable mould was washed away, and nothing remained but a red earth, cut into square channels, like troughs, with a narrow ridge interposed between them. Above was conducted a head-stream of water, let down through these troughs, which were all on an inclined plane. The lighter parts of the clay were washed away, and the gold remained behind." This is a mode of operation which might be adopted on a large scale in the auriferous fields of Australia, provided a combination of interest could be brought about.

From 1600 to 1700 the entire supply of gold for Europe was obtained from America, which mines are estimated in the one hundred years to have produced 337,500,000*l.* worth of the precious metals. Of this 33,000,000*l.* were sent to the Philippine Islands, India, and China; and it is estimated that 60,000,000*l.* of gold were employed in decorating churches, and for ornamental purposes generally; and if 34,000,000*l.* is allowed as the

loss by wear and other causes—a very low estimate—the amount of coined money in 1699 in Europe will be 297,000,000*l.* sterling. During the eighteenth century the supply of gold and silver was still mainly derived from the Americas,—the great mine of Valenciana producing 125,000*l.* sterling per annum for forty years, and the district of Zaccatecas adding largely to the amount, although these were rapidly failing towards the end of the century. The following table from Humboldt puts the produce of this period in the clearest light :—

In ten years, from	1700 to 1709	..	£10,777,298
"	1710 to 1719	..	13,697,297
"	1720 to 1729	..	17,131,921
"	1730 to 1739	..	18,860,355
"	1740 to 1749	..	23,302,633
"	1750 to 1759	..	26,197,936
"	1760 to 1769	..	23,506,012
"	1770 to 1779	..	34,912,858
"	1780 to 1789	..	40,318,948
"	1790 to 1799	..	48,191,711
"	1800 to 1809	..	47,142,814
			£304,039,783
This is an exact return from the several mints.			
The gold and silver of Mexico which did not pay duty and passed into other channels, is said to be		..	60,000,000
			£364,847,739
Equal to an annual product, during the whole period of 110 years, of		..	£3,316,706

The contraband trade was very extensively carried on during this period, and it is supposed that in addition to the following quantities paying duty,—

Peru	£100,169,524
Columbia	57,341,666
Chili	19,532,166
Buenos Ayres	96,250,000
	£273,293,356
There must be added an amount of contraband	£68,323,339

making more than 340,000,000*l.* to be added to the produce of Mexico. According to the most careful estimation there was produced between 1700 and 1810,—

Spanish America	£706,464,434
Portuguese America	80,000,000
	£786,464,434

The gold dust of Africa, with the gold and silver of Europe, may be estimated at the annual value of 900,000*l.*, and the annual value of the precious metals from Spanish and Portuguese America being 7,000,000*l.*, the annual increase of the wealth of Europe during the last century was at the rate of 8,000,000*l.* This launches us upon our own times, when science has been made available to economise the products of nature. It is not easy at once to estimate the produce of the precious metals since 1810.

Mr. M'Culloch, mainly relying on the authority of Humboldt, estimates as follows for the annual value :—

	Value of Gold and Silver in Dollars.
Vice-Royalty of New Spain	23,000,000
Vice-Royalty of Peru	6,240,000
Captain-Generalship of Chili	2,060,000
Vice-Royalty of Buenos Ayres	4,850,000
Vice-Royalty of New Granada	2,990,000
Brazil	4,360,000
	43,500,000

Taking the dollar at 4*s*., this will give 8,700,000*l*. as the total produce of the American mines. The gold coined in the mints of the Mexican Republic in 1840 and 1841, was

	1840. Dollars.	1841. Dollars.
Mexico	71,207	97,628
Guanaxunto	437,168	440,240
Duranto	243,082	155,140
Chihuahua		63,050

The American mines in 1840 were estimated as follows :—

	Dollars.
Mexican	17,500,000
Peruvian	5,210,000
Bolivian	3,000,000
Chilian	2,500,000
Panama	1,000,000
Brazil	1,500,000
	30,710,000

Equal to 5,600,000*l*. per year.

Carolina, Georgia, and other parts of the United States, have produced considerable quantities of gold. The following reduction from an enlarged return will sufficiently show the value of this supply :—

	Dollars.
In 1828	46,000
1832	678,000
1834	898,000
1838	435,000
1841	542,117

The great increase of gold has, however, been from the mines of Russia. The Russian pood is equivalent to about forty pounds troy.

		Poods.
In 1830 the gold washings of Siberia produced		5
1836	.. ..	105
1837	.. ..	132
1841	.. ..	358
1842	.. ..	631

Mr. M'Culloch, quoting from a Russian journal, informs us that in addition to the above quantity of 631 poods in 1842, the silver from the mines of Kolyvan yielded in the course of the same year 30 poods of gold; while the washings and mines in the Ural mountains yielded no fewer than 310 poods, making a total of 971 poods, equal to 42,571lbs. troy, which, at 46*l.* 14*s.* 6*d.* per lb., is equivalent to 1,989,128*l.* 11*s.*

Sir Roderick Murchison is disposed to consider the production of gold at the present time in Russia to be nearly equal to 3,000,000*l.* sterling per annum; and, from the following returns, it will be seen how near the truth is the estimation of this eminent geologist.

We learn from a communication from Russia, with which we have been kindly favoured by Sir Roderick Murchison, the quantity of gold and silver raised in Russia since 1847.

Gold :—

1847	.. ..	1700 poods.
1848	.. ..	1660
1849	.. ..	1530
1850	.. ..	1490
1851	.. ..	1266
		7546

Equal to about 296,932lbs. troy, in five years.

Silver about 1200 poods per annum.

From Erman's "Archives" we find that in the year 1851—

The gold-washing of the Uralian Washing and Amalgamation Works produced ..	332 poods.
The Nertschinsk works	67 „
The remaining West and East Siberian Washings	1107 „
Total washed gold obtained in Russia in 1851	1507 „
Produce of Altai Mountains and of Nertschinsk Siberian works added	39 „
	1546 poods.

Which is 300 poods more than Sir Roderick Murchison's account, producing 64,932lbs. troy of gold during last year.

It is now well that we should examine the present rate of increase of the precious metals in Europe. This I am only enabled to do from the necessarily short time I have had at my disposal for so large a subject by giving the imports into this country, which are as follows, for the years 1850, 1851, 1852, as furnished me from the books of the Bank of England :—

GOLD IMPORTED.

	1850.	1851.	To June 30, 1852.	Supposing importation to continue at same rate to end of year.
South America	£287,000	£185,000	£33,000	
Africa	60,000	28,000	15,000	
Russia	237,000	905,000	90,000	
Turkey	262,000	140,000	150,000	
California	700,000	1,300,000	1,100,000	£2,000,000
Australia	..	40,000	2,600,000	5,200,000
United States	..	3,300,000	2,000,000	4,000,000

We may also infer very nearly the actual produce of the mines in Mexico by the—

Total Amount of Gold and Silver coined in the Mints at Mexico for Twelve Months, 1849.

	GOLD.	SILVER.	TOTAL.
Chihuahua	..	$332,208	$332,208
Guadalajara	$21,652	938,890	960,542
Guadalupe y Calvo ..	..	1,045,185	1,045,185
Guanajuato	861,480	10,661,600	11,523,080
Mexico	125,920	2,430,778	2,556,698
San Luis Potosi	..	2,052,268	2,052,268
Zacatecas	..	7,129,920	7,129,920
Durango	25,057	1,483,569	1,508,626
Culiacan	317,307	929,571	1,246,876
	$1,351,416	$27,003,989	$28,355,405

Gold, $1,351,416 at 4s.	£270,243	4	0	These figures will be pretty near the truth for 1851.
Silver, 27,003,989	5,400,797	16	0	

Spain.

The value of silver produced in Spain in the year 1851 amounted to nearly ..	£300,000	0	0

South America.

St. John del Rey	£119,683	4	10
Imperial Brazilian	8,000	0	0
Mariquita and New Granada Co. ..	13,395	0	0

The produce of a single mine for a period of twenty-five years will show the general character of a gold mine, since the prevailing conditions are exceedingly similar.

Statement of Produce of Gold at Gongo Soco Mine.

	lbs.	oz.	dts.	grs.
1826.				
1st 6 mths. ..	203	8	13	7
2d 6 mths. ..	349	1	2	11
1827.				
1st 6 mths. ..	661	6	7	14
2d 6 mths. ..	1348	5	15	2
1828.				
1st 6 mths. ..	588	7	8	9
2d 6 mths. ..	473	7	0	23
1829.				
1st 6 mths. ..	2037	4	12	15
2d 6 mths. ..	2153	7	1	17
1830.				
1st 6 mths. ..	1442	7	19	7
2d 6 mths. ..	1597	10	4	13
1831.				
1st 6 mths. ..	1503	1	9	10
2d 6 mths. ..	1528	9	3	19
1832.				
1st 6 mths. ..	1830	4	18	22
2d 6 mths. ..	2371	9	15	20
1833.				
1st 6 mths. ..	1123	10	14	12
2d 6 mths. ..	1864	5	15	14
1834.				
1st 6 mths. ..	665	4	4	6
2d 6 mths. ..	988	3	0	0
1835.				
1st 6 mths. ..	665	10	14	0
2d 6 mths. ..	408	6	0	0
1836.				
1st 6 mths. ..	662	7	4	0
2d 6 mths. ..	337	5	0	14
1837.				
1st 6 mths. ..	817	5	17	9
2d 6 mths. ..	580	3	10	0
1838.				
1st 6 mths. ..	570	9	8	7
2d 6 mths. ..	472	5	19	18
1839.				
1st 6 mths. ..	824	4	10	17
2d 6 mths. ..	564	6	7	21
1840.				
1st 6 mths. ..	748	6	9	6
2d 6 mths. ..	276	11	0	0
1841.				
1st 6 mths. ..	410	3	17	12
2d 6 mths. ..	520	2	9	12
1842.				
1st 6 mths. ..	621	2	17	10
2d 6 mths. ..	369	8	11	8
1843.				
1st 6 mths. ..	307	8	14	8
2d 6 mths. ..	298	10	12	12

Produce of Gold, &c.—*continued.*

	lbs.	oz.	dts.	grs.
1844.				
1st 6 mths. ..	411	8	19	12
2d 6 mths. ..	162	9	1	0
1845.				
1st 6 mths. ..	95	7	0	0
2d 6 mths. ..	150	0	17	0
1846.				
1st 6 mths. ..	178	10	15	0
2d 6 mths. ..	116	4	15	0
1847.				
1st 6 mths. ..	68	0	17	0
2d 6 mths. ..	91	7	1	0
1848.				
1st 6 mths. ..	86	4	7	0
2d 6 mths. ..	86	8	1	0
1849.				
1st 6 mths. ..	90	2	6	0
2d 6 mths. ..	67	4	15	0
1850.				
1st 6 mths. ..	68	4	16	0
2d 6 mths. ..	72	7	1	0
1851.				
1st 6 mths. ..	45	0	10	0
2d 6 mths. ..	61	1	1	0

Statement of Produce from "Bananal."

	lbs.	oz.	dts.	grs.
1847.				
2d 6 mths. ..	66	5	17	12
1848.				
1st 6 mths. ..	3	1	13	0
2d 6 mths. ..	175	4	0	0
1849.				
1st 6 mths. ..	149	11	3	0
2d 6 mths. ..	93	0	8	0
1850.				
1st 6 mths. ..	143	6	11	0
2d 6 mths. ..	94	10	16	0
1851.				
1st 6 mths. ..	49	9	17	0
2d 6 mths. ..	15	5	5	12

From the information with which I have been most kindly furnished by Messrs. Mocatta and Goldsmig, I learn that the aggregate production of the precious metals in Mexico and South America does not appear to have increased at all within the last four or five years. The

amount of silver received into England in 1851 was about 5,000,000*l.* value, and of gold about 11 or 12,000,000*l.* in the whole. The United States are said to have coined 62,000,000 dollars in gold; and France about 200,000,000 francs in the same year.

It has been estimated by some that 23,000,000*l.* of gold and silver will be added to our store of precious metals this year. This appears to be one of the exaggerated statements arising out of the fever of the day: we shall not receive more than 11,000,000*l.* from the United States, California, and Australia; and if we receive 3,000,000*l.* more from all the other sources of supply, it will be as much as we may expect. Many former sources of supply are cut off, and the probability is that we shall not receive nearly so large a quantity. Let us examine briefly the rate of produce in the Australian mines:—

The Sydney district produced, from

29th May, 1851, to 31st Oct. 1851,	67,152	oz. of gold,	value	£214,886	0
Or to Nov. 10, 1851,	79,340	„	„	257,855	7
And to Dec. 31,	142,975	„	„	464,668	15

In the Victoria district, to the end of December, 1851,

Ballarat produced	25,108 oz.	value	£75,324
Mount Alexander	30,007	„	96,021

In December, there was shipped from Victoria,			145,116 oz.
On the 8th January	„	„	75,188 oz.

Only about two-fifths of the gold realised is sent by the Government escort; hence there is much difficulty in arriving at the actual amount. But the imports to this country may be safely relied on as representing the maxi-

mum produce of our colonial gold fields and the auriferous districts of America. The question has arisen, May we expect the price of gold to be lessened from the influx of this metal? Annexed are some of the rates of value of a pound troy of gold at different periods:—

VALUE OF THE TROY POUND OF GOLD.

Year.		£	s.	d.	Year.		£	s.	d.
1344	..	15	0	0	1549	..	34	0	0
1345	..	13	3	4	1605	..	40	10	0
1347	..	14	0	0	1626	..	44	10	0
1412	..	16	13	4	1718	..	46	14	6
1464	..	20	16	8	1817	..	46	14	6
1526	..	27	0	0					

Which is the price at which fine gold still continues: the gold of our standard being at 3*l.* 17*s.* 9*d.*

The arguments relative to the currency and the alteration in the standard of value go somewhat beyond my subject. I give you facts, which may be relied on, and, with these, I must leave others better acquainted with commercial economy than myself to deal. Howbeit, let it not be forgotten that the exportation of coin from England is rapidly increasing, and the English sovereign is becoming every year more extended as a medium of exchange. Formerly the Spanish dollar passed everywhere, and now the English sovereign is taken as current coin over three-fourths of the globe; and its exportation keeps pace with the importation of raw gold.

From November 1850 to June 1851, the Bank of England issued 9,500,000 sovereigns, being at the rate of 18,000,000 a-year; and so great is the demand for our gold coins that Sir John Herschel informs me since

November last there have been coined at the Mint 3,500,000 sovereigns and half-sovereigns, and the rate of production can scarcely keep pace with the increasing demand. This must have a material influence in maintaining that stability which is desirable in our standard of value.

It may be interesting to know that from a very correct account kept at the Bank when the light coin was called in in 1842, that 12,000,000*l.* were received light, and that 36,000,000*l.* still circulated of full weight; 40,000,000*l.* may therefore be regarded as the quantity of gold coin in circulation, allowing from three to four per cent. for the natural wear of the coin.

The following table gives, over an extended period,

The Coinage of Great Britain.

Reign of	No. of Years.	Gold.	Silver.	Total Money.
		£	£	£
James I. .	22	3,666,389	1,807,277	5,473,666
Charles I. .	35	3,465,188	9,776,544	13,241,732
Charles II. .	22	4,177,253	3,722,180	7,899,433
James II. .	4	2,113,638	2,115,115	4,228,753*
William & Mary	12	2,314,889	7,093,074	9,434,963
Anne . .	13	2,484,531	618,212	3,102,743
George I. .	14	8,492,876	233,045	8,725,921
George II. .	37	11,662,216	304,360	11,966,576
George III. .	61	75,753,443	6,996,765	82,750,206
George IV. .	9	36,147,700	2,216,168	38,363,868
William IV. .	7	14,000,000	2,800,000	?
Victoria:				
1837 to 1841	4	4,991,210	889,102	5,880,312
1842 to 1847	5	29,886,457	2,440,614	32,327,071

Total Coinage of 32 years, ending 1847.

Gold.	Silver.	Copper.
£90,029,383	£13,590,000	£248,210

* This included £1,596,799 of base money coined for Ireland.

As adding to our national wealth the production of silver must not be forgotten. This subject is equally extensive as the subject of gold, and one, therefore, into which I cannot enter further than to state that the British Isles produce annually 674,458 ounces, value 168,614*l.*; the Spanish lead imported yields 166,700 ounces, worth 41,675*l.*; and the silver ores and argentiferous copper ores imported give not less than 150,000*l.* of this metal.

I intended entering into a consideration of the quantity of gold which every year is employed in arts and manufactures, and thus regularly removed from the stock of our circulating wealth. Mr. M'Culloch, following Jacob, estimates the present annual consumption of the precious metals in the arts as follows:—

The United Kingdom	£2,500,000
France	1,000,000
Switzerland	450,000
The rest of Europe	1,600,000
North America	500,000
Making a total consumption of	£6,050,000

From information with which I have been most obligingly furnished, I learn that in Birmingham not less than 1000 ounces of fine gold are used every week, and that the weekly consumption of gold-leaf is as follows:—

London	400 ounces.
Edinburgh	35
Birmingham	70
Manchester	40
Dublin	12
Liverpool	15
Leeds	6
Glasgow	6
Total	584 weekly,

of which an eminent gold refiner informs me not one-tenth part can be recovered. For gilding metals by the electrotype and the water-gilding processes, not less than 10,000 ounces of gold are required annually. One establishment in the Potteries employs 3500*l.* worth of gold per annum, and nearly 2000*l.* worth is used by another. The consumption of gold in the Potteries of Staffordshire for gilding porcelain and making crimson and rose colour varying from 7000 to 10,000 ounces per annum.

The consumption of gold and silver in Paris has been fairly estimated at 14,552,000 francs a-year. The wear upon gold coin in circulation is about four per cent per annum; and from this knowledge and the foregoing details we may deduce the fact that nearly 2,000,000*l.* a-year is necessary to maintain the metallic currency at its present value; therefore a supply of between 8,000,000*l.* and 9,000,000*l.* is necessary for the arts and manufactures, and the purposes of coinage; and when we add to this our constantly increasing exportation of coin, it appears that the influx of Australian and Californian gold will produce but little change in its value in Europe.

In the very rough sketch of the history of gold which I have given you, I hope I may have sufficiently indicated the fact that there is evidently a law of distribution and a providential order in the sequence of discoveries. Man started on his race of civilisation from the great plains to south of the Caucasus. The Indus and the Euphrates were the earliest spots from which he obtained gold. Nubia and Ethiopia on the south, and Siberia on the north, in the course of a short time handed up their auri-

ferous treasures to gratify human necessity and to indulge human luxury.

Europe then began to unfold its golden stores, and Illyria and the Pyrenees, together with the lands of the Hungarians, and many parts of Germany, to the Rhine, were sought successfully for gold. Our islands yielded something to the store; and then the new world of the Americans opened by Columbus a source from which the old world was to supply its golden waste. On and on still westward rolled the golden ball—which, in many respects, was not unlike the ball of the Oriental tale—until, at length, it rested in California. Europe and Asia rush equally to that new El Dorado, and the man of China is found at the side of the English gold-streamer. Then, as if to double the girdle, the islands of the Pacific and our own Australia open their exceeding stores.

My colleagues have taught you where and how you are to discover and work for gold. My humble task has been to give you some idea of the rate of production during the time of history, and to endeavour to dispel the idle dreams of golden mountains and of golden rivers. Gold is in Australia; but it will not increase either your health or your happiness. You possess within yourselves mines of richer treasure than those of Mount Alexander—take them with you as treasures which you will not barter for gold—and may all happiness attend the possessors of a Briton's unwearying *industry*, the inheritors of an Englishman's *contentment*.

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